Ecosystem Restoration for Fisheries Resources through Water Temperature Reduction in the Lower American River

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SECTION 1.0

INTRODUCTION

1.1 Purpose and Scope

This report documents the development of a fisheries ecosystem restoration plan for the American River Watershed Investigation. It describes the plan formulation process for identifying potential alternatives for reducing water temperature in the Lower American River during critical stages in the life cycle of Sacramento River fall/late fall–run chinook salmon and Central Valley steelhead to increase the numbers of these fish spawning naturally in the river. The Sacramento River fall/late-fall run chinook salmon is a candidate threatened species under the federal Endangered Species Act, and Central Valley steelhead are listed as threatened under the federal Endangered Species Act. This report is developed as a parallel, companion study for the American River Watershed Long-Term Study ecosystem effort covering 4 floodplain sites in the Lower American River and includes:

- descriptions of the setting and environment, including location, land use, and existing conditions (without the proposed project);
- a summary of the priority problems and restoration opportunities;
- restoration goals and objectives, planning criteria, and constraints;
- descriptions of potential restoration measures;
- a determination of cost effectiveness; and
- plan recommendations.

1.2 Mission and Vision of Ecosystem Restoration

Ecosystem restoration is one of the primary missions of the U.S. Army Corps of Engineers' (Corps') Civil Works program. The purpose of ecosystem restoration is to restore significant ecosystem function, structure, and dynamic processes that have been degraded. The intent of restoration is to reestablish the attributes of a naturalistic, functioning, and self-regulating system.

The Corps' mission of protecting, restoring, conserving, and managing ecological resources has taken on greater importance over recent decades. The Lower American River study is an example of evaluating ecosystem restoration opportunities as part of a broader regional water resources management program authorized by Congress.

The stated purpose of ecosystem restoration efforts is to comprehensively examine the problems that contribute to ecosystem degradation and to develop alternative means of solving these problems.

1.3 Background

The American River drains a watershed of approximately 2,100 square miles (U.S. Bureau of Reclamation 1996) and is a major tributary of the Sacramento River. Historically, the American River provided more than 125 miles of riverine habitat to anadromous and resident fish. Currently, use of the American River by anadromous fish is limited to the 23 miles of river below Nimbus Dam (i.e., the Lower American River) (Jones & Stokes 2000).

The river is used by approximately 40 species of fish, including numerous resident native and introduced species and several anadromous species. A number of species are of primary management concern because of their declining status or their importance to recreational and/or commercial fisheries. These species include fall/late fall–run chinook salmon, Central Valley steelhead, and Sacramento splittail. The Central Valley steelhead evolutionarily significant unit (ESU), found in the Lower American River, was listed by the National Marine Fisheries Service (NMFS) as threatened with an effective date of May 18, 1998. Recreationally and/or commercially important anadromous species of the Lower American River include fall-run chinook salmon, striped bass, and American shad. A variety of centrarchid species are also recreationally important. Fall-run chinook salmon remain a candidate species for NMFS. Sacramento splittail was listed by the U.S. Fish and Wildlife Service (USFWS) as threatened with an effective date of March 10, 1999 (Jones & Stokes 2000).

A Baseline Report of aquatic resources within the Lower American River was prepared through the efforts of the Lower American River Task Force—Fisheries and Instream Habitat Working Group (FISH Group). The FISH Group is comprised of stakeholders representing the California Department of Fish and Game (DFG), NMFS, California Department of Water Resources (DWR), and the CALFED Bay-Delta Program, to name a few. Further details on the Lower American River Task Force are provided in section 3. The Baseline Report established that flow and temperature improvements have the greatest potential for habitat enhancement with respect to fish of primary management concern.

Efforts to improve the flow release regime in the Lower American River are currently underway through the Sacramento Water Forum. The Sacramento Water Forum was formed in September 1993 to evaluate water resources and future water supply needs of the Sacramento metropolitan region. In December 1994, the Water Forum formalized the process of updating the Lower American River flow release regime by convening the Fish Biologists Working Group. This group developed the initial methodology that matched river releases to varying life cycle needs of the fishery. In January 1999, the Water Forum, USFWS, and U.S. Bureau of Reclamation (Bureau) agreed to continue working on a proposal to be presented to the State Water Resources Control Board (SWRCB) with the intent to update the flow release regime in the Lower American River. The objective of the proposal is to increase the minimum release requirement for the river in conjunction with establishing an adaptive management process for Folsom Reservoir and Lower American River operations (Surface Water Resources, Inc. 2001a). Because this proposal will address flow regime, 1 of the 2 issues that have the greatest potential for improvement of fisheries habitat, this report will focus on the second issue, temperature.

The presence of Sacramento splittail in the Lower American River is believed to be largely restricted to their upstream and downstream movements associated with spawning (Jones & Stokes 2000). The Baseline Report identifies a reduction in shallow inundated habitat in the Lower American River as a stressor for Sacramento splittail. Splittail use this habitat for spawning and early rearing (Surface Water Resources, Inc. 2001a). Splittail have also been found to tolerate a wide range (44.6–91.4ºF) of water temperatures in the laboratory (Sommer 1997). The Recovery Plan for Sacramento–San Joaquin Delta Fishes notes that the primary reasons for splittail decline are changed estuarine hydraulics, modification of spawning habitat, climatic fluctuations, introduced species, predation, and exploitation. For these reasons, and because high temperature is not an identified stressor for Sacramento splittail, this report does not focus on Sacramento splittail as a species of primary management concern. Rather, this report will focus on reducing temperature during the critical life stages for 2 fish species of management concern: fall/late fall–run chinook salmon and Central Valley steelhead.

Current fall-run chinook salmon and steelhead production in the Lower American River is believed to be limited, in part, by inadequate instream flows and high water temperatures during portions of the species' freshwater residency in the river. High water temperatures during fall can delay the onset of spawning by chinook salmon, and river water temperatures during spring and summer can become unsuitably high for juvenile salmon and steelhead rearing (Jones & Stokes 2000).

Water temperatures are affected by river flow rates, meteorology, and the temperature of water released from Folsom Reservoir. The latter factor has a significant effect on Lower American River temperatures, but relatively little attention has been given in the past to managing the temperature of water released from the dam throughout each year. Consequently, water temperatures could be improved, especially during the late spring to early fall when seasonal temperatures are highest, to benefit steelhead and fall-run chinook salmon by improving the management of Folsom Reservoir release temperature (Surface Water Resources 2001a).

Other project area conditions are described in the following chapter.

1.3.1 Problems and Opportunities

A summary of the problem and opportunities for fisheries and aquatic resources habitat within this ecosystem is presented below.

<u>Problem.</u> High temperatures in the Lower American River are affecting the spawning and other life stage behavior of fish species of highest management concern (i.e., fall-run chinook salmon and federally listed as threatened steelhead), resulting in reductions of the species' natural production, and populations in the Lower American River. The current structural and operational limitations of Folsom and Nimbus Dams hinder the ability to optimize management of the coldwater pool within Folsom Reservoir and provide maximum thermal benefit to downstream late/late fall–run chinook salmon and Central Valley steelhead during critical life stages.

Opportunity: Provide a flexible mechanism for manipulating the timing, temperature, and rate of flow released from Folsom and Nimbus Dams to produce the most immediate and effective temperature reduction for fish ecosystem restoration.

Opportunity: Achieve restoration of native fish populations (via an increase in natural production) through improved water temperature management of Folsom Reservoir's coldwater pool. Restoration of native fish populations is an integral element of the overall restoration of significant ecosystem function, structure, and dynamic processes.

SECTION 2.0

EXISTING AND FUTURE WITHOUT-PROJECT CONDITIONS

2.1 General Setting

The American River originates in California's central Sierra Nevada. The North and Middle Forks join near the City of Auburn, California, before emptying into Folsom Reservoir, which is impounded by Folsom Dam. The South Fork also drains into Folsom Reservoir. Releases from Folsom Dam enter Lake Natoma before being discharged into the Lower American River. The river below Lake Natoma is entirely regulated by flows from these impoundments. The river joins the Sacramento River near downtown Sacramento. Water surface elevations (stage) in lower reaches of the American River are strongly influenced by flows from the Sacramento River (Jones & Stokes 2001).

2.1.1 Location

The Lower American River includes the 23 river miles (RMs) between Nimbus Dam and the river's confluence with the Sacramento River. The river is bounded in much of this reach by levees on the north and south sides. Flood protection levees begin at the confluence with the Sacramento River and extend upstream to approximately RM 14 on the north bank and RM 11 on the south bank. The American River Flood Control Project levees are within the jurisdiction of the Corps, American River Flood Control District (ARFCD), Sacramento Area Flood Control Agency (SAFCA), and Reclamation Board of the State of California. These levees provide flood protection for cities and communities of Rancho Cordova, Carmichael, Orangevale, Citrus Heights, Arden-Arcade, and Sacramento (Jones & Stokes 2001). These levees contain high velocity flows that historically would spread over the now urbanized floodplain. Upstream of the project levees, the river is confined primarily by bluffs, although some private levees locally confine floodflows.

2.1.2 Land Uses

The American River Parkway (Parkway), owned and managed by Sacramento County, borders much of the river. The principal management document for the natural resources of the Lower American River is the American River Parkway Plan (1985). The Parkway lies almost entirely in the Lower American River floodplain and is valued by local residents for its natural beauty and recreation resources. The Parkway encompasses approximately 5,000 acres of developed parkland (including multiuse trails, picnic areas, boating access, playgrounds, fishing ponds, and golf courses) and undeveloped natural areas (including wetlands, riparian habitat, floodplain habitats, and mine tailings). The Parkway is managed and maintained by the Sacramento County Department of Parks, Recreation, and Open Space. Relatively small portions of the Parkway corridor are in private ownership, including the floodplain adjacent to the California State Fair and Exposition Center (Cal Expo) and the Urrutia mining pit. Near Arden Bar, the Sacramento County Sheriff's Department operates and maintains a training facility (Jones & Stokes 2001).

2.1.3 Existing Conditions

Watershed Development and Migration Barriers

Historically, anadromous salmonids had access to more than 125 miles of habitat in the upper reaches of the American River Basin. Since the early 1900s, however, access has been impeded by dams constructed for mining debris containment, flood control, and diversions. Many of these dams had inadequate or no fish ladders. In 1950, Old Folsom Dam's fish ladder was destroyed by floods, blocking fish passage upstream of RM 25. Construction of Folsom and Nimbus Dams in 1955 permanently blocked upstream passage past RM 23, and reportedly blocked approximately 70% of the spawning habitat historically used by chinook salmon and all of the spawning habitat historically used by steelhead. Anadromous salmonids are now restricted to the lower 23 miles of the American River from Nimbus Dam to the confluence with the Sacramento River, and the Nimbus Salmon and Steelhead Hatchery (Surface Water Resources 2001a).

Folsom Reservoir is managed to fulfill the multipurpose objectives of the Central Valley Project (CVP) flood control, water supply, fish and wildlife protection, recreation, and power production. Because of the finite nature of the hydrological water supply, each multipurpose objective is affected by the others in terms of determining operational management choices (magnitude and frequency of river releases, time of year, reservoir elevation and storage, coldwater management strategy) and management priorities (Surface Water Resources 2001a).

Nimbus Dam, approximately 7 miles downstream from Folsom Dam, serves as the regulating facility for hydropower releases from Folsom Dam. It also serves as a diversion dam for the Folsom South Canal. Its reservoir, Lake Natoma, provides flat-water recreation but not significant water storage capabilities (Surface Water Resources 2001a).

Flood Control in Lower American River Channel

The Lower American River channel extends from the Sacramento River to Lake Natoma. Confined by high ground along its upper reach, the Lower American River channel is leveed along its north and south banks for about 13 miles from the Sacramento River to the easterly end of Arden Way in Carmichael on the north and to the Mayhew Drain on the south. Both the south levee and the north levee of Cal Expo are units of the Sacramento River Flood Control Project (SRFCP), originally authorized by Congress in 1917 and consisting of a comprehensive system of levees, overflow weirs, drainage pumping plants, and flood bypass channels on the Sacramento River and lower reaches of its main tributaries. The south levee was upgraded to federal standards in 1948, the north levee in 1955. These levees were designed to control flows up to 180,000 cubic feet per second (cfs) and maintain 3 feet of levee freeboard. Their design heights were determined when there was no confinement of flows along the north bank upstream of the present location of Cal Expo and agricultural lands in the area now known as Campus Commons provided overbank storage during large floods in the watershed. This storage was eliminated by construction of the north levee upstream of Cal Expo, which significantly narrowed the floodway, particularly in the river reach adjacent to California State University, Sacramento. The levee comprises the American River Levee Project and was constructed in conjunction with Folsom Dam (Jones & Stokes 2000). These levees contain high velocity flows that historically would spread over the urbanized floodplain.

The Lower American River floodplain covers approximately 6,000 acres north of the river, including Cal Expo, the Campus Commons subdivision, and a portion of North Sacramento south of Arcade Creek. South of the river, the floodplain covers about 45,000 acres and encompasses much of downtown Sacramento (Jones & Stokes 2001).

Current federal requirements for flood control at Folsom are set forth in a flood-control diagram issued by the Secretary of the Corps on November 7, 1986, under the authority of the Flood Control Act of 1944. This diagram requires the Bureau to reduce Folsom's water conservation pool to no more than 575 thousand acre feet (TAF) during the flood season (December through March) (Jones & Stokes 2000).

Hydrology

Changes caused by the construction of Folsom Dam and development along the American River dramatically altered the hydrology of the Lower American River. Flows in the Lower American River are now more evenly distributed throughout the year (Surface Water Resources 2001a).

Annual peak flows historically occurred in spring, but now occur in early winter. Historically, summer and early fall were characterized by very low flows and high water temperatures. Summer flows are higher and water temperatures lower than they were historically, which results from the ability to store runoff and regulate flows and to make selective water temperature withdrawals from the penstock inlet ports at Folsom Dam. Under current hydrologic conditions, the Lower American River, which historically was not used extensively by anadromous salmonids for spawning, can support naturally spawning fish populations, including fall-run chinook salmon and steelhead (Surface Water Resources 2001a).

Geomorphology

The current geomorphic character of the Lower American River has been contoured by its hydrologic history. Gold mining from 1855 to 1884 inundated the river's spawning grounds with an estimated 257 million cubic yards of gravel, sand, silt and debris. Five to 30 feet of gravel, sand, and silt were deposited on the bed of the Lower American River from the present location of Nimbus Dam to the mouth because of hydraulic mining and dredging. The riverbed at the mouth of the river underwent extreme change because 15 square miles were covered with debris. Since 1955, the Lower American River has generally incised down to its previous bed elevation.

Although dams block further influx of sediment from upstream areas, banks, points, and bars still serve as sources of stored sediment in the Lower American River. Generally, the riverbed is mobilized at flows of about 50,000 cubic cfs, although parts of the riverbed remain immobile. Between 1968 and 1986, the Lower American River exhibited 1.1–13.9 feet of erosive lateral migration per year. Under the river's current sediment transport and erosive mechanisms, there is no indication that the Lower American River will be starved of suitable spawning gravels in key reaches within the near future (Surface Water Resources 2001a). Current spawning gravel conditions are discussed below.

Aquatic Habitat

Geomorphic and hydrologic changes have also impacted the in-stream and riparian habitat of the Lower American River. There have been decreases in shaded riverine habitat, habitat complexity and diversity, and woody debris, and an increase in invasive exotic vegetation. The artificial levee system has caused localized bank erosion, incision, and general channelization of the river corridor. Modification of the spring and summer hydrograph from flow regulation has likely affected the potential for cottonwood revegetation. Reduction in the abundance of near-channel cottonwoods has reduced shaded channel surface. Large woody debris is noticeably deficient in many stretches of the Lower American River, particularly in upstream areas (Surface Water Resources 2001a).

Spawning gravels in the Lower American River have been evaluated in several studies in the past 12 years. One of the most thorough of those studies was undertaken by the California Department of Fish and Game in 1993 (Vyverberg et al. 1997). Their results indicated that the quantity and quality of spawning gravels appeared suitable based on gravel size, distribution, and other factors. The lifetime of the existing spawning gravel in the upper reaches (upper 9 miles) of the Lower American River is not known. Although the amount of gravel stored in bank is thought to be plentiful, the rate of recruitment and bed transport is unknown (Surface Water Resources 2001a).

Temperature and Management of Temperature in the Lower American River

Seasonal water temperatures in the Lower American River have been substantially altered by reservoir operations. Figure 2-1 illustrates the increase in water temperature before and after the construction of Folsom and Nimbus Dams.

Seasonal water temperature at Folsom Reservoir and the Lower American River are lowest during winter, increase through spring, are highest during summer, and decrease again in fall. The temperature of inflow stored during the filling of Folsom Reservoir gradually increases through spring and into summer. Because cooler water is denser than warmer water, Folsom Reservoir develops a stratification of temperature, with cooler water at the bottom (Surface Water Resources 2001a).

Water temperatures can reach unsuitable levels for juvenile salmon and steelhead trout during spring and summer, especially in dry and critically dry water years. High summer water temperatures severely limit natural steelhead production in the Lower American River because juvenile steelhead reside in fresh water for a full year or more before migrating to sea. Significant reductions in Folsom Reservoir storage in dry and critically dry years can cause water temperatures to exceed suitable levels for chinook salmon egg survival in October and November, adversely affecting both natural and hatchery production. The specific effects of high temperatures on different life stages of fall/late fall–run chinook salmon and steelhead are discussed in greater detail below in the Fish section.

The existing management principles for Folsom Reservoir's coldwater and fishery flow emphasize the capture of winter and spring cold reservoir inflows to create a coldwater reserve to be released during summer and fall for Lower American River fishery objectives (Surface Water Resources 2001b). The temperature of water released from Folsom Reservoir is manipulated by releasing water from various elevations through the temperature control shutter panels on each of the 3 power penstock intakes (Surface Water Resources 2001b).

The intake to the Folsom Dam power plant penstocks has 9 water release shutters that can be used to control the elevation of the stored water released from the dam. The more independently the shutters can be operated, the greater control there is over the depth and the temperature of water released throughout the summer.

Historically, the temperature control shutter panels have been bolted together in 2 configurations to comprise each group of 9: 1-1-7 and 3-2-4. In the 1-1-7 configuration, the top 2 panels could be raised individually, and the remaining 7 lower panels were bolted together and could be raised only as a unit after the top 2 panels were raised. In the existing 3-2-4 configuration, the top 3 panels are bolted together and can be raised as a unit, followed by the next 2 panels bolted together as a unit, after which the remaining 4 panels can be raised as a unit. This configuration allowed for 4 distinct elevations from which Folsom Dam releases could be drawn. Units of shutter panels can be removed or replaced, allowing for releases to be made without any panels in place or with the lowest, 2 lowest, or all 3 units in place. The structure of the Folsom Dam shutter housing currently limits the number of shutter panel units to 3 units (Surface Water Resources 2001b).

Shutter position changes at Folsom Dam are currently performed manually. A crew of 3 people—1 to operate the gantry crane trolley beam and hoist, 1 to check operations and signal the crane, and 1 to set latches, pull pins, etc.—is required to change the shutter positions at Folsom Dam. The operation requires 8–12 hours to adjust all shutter groups and interferes with traffic using the road across the dam. Because of the manual labor requirements and the need to schedule potential traffic interruptions, the current configuration changes only 3–4 times per year (Surface Water Resources 2001b).

Folsom Dam shutter management allows some flexibility in the management of the coldwater pool. By operating the shutters to withdraw water from the highest available reservoir elevation during winter and spring, when water temperatures are suitably cold for fishery protection, the lowest reservoir elevation coldwater reserves can be conserved for later thermal protection benefits. During the critical thermal fishery protection season (generally summer and fall), temperature control shutters are managed to achieve as much thermal protection as possible, given the physical limitations of the current shutter configuration (Surface Water Resources 2001b).

Fish

Although development in the watershed has drastically and permanently transformed the Lower American River ecosystem, the river still supports a very diverse and relatively prolific array of fish species. The Lower American River supports approximately 40 species of native and nonnative fish, including several anadromous species. Two species of anadromous salmonids inhabit the Lower American River: fall-run chinook salmon and steelhead (Surface Water Resources 2001a).

Chinook Salmon. Prior to the construction of Folsom Dam, the American River with more than 125 miles of accessible riverine habitat, historically supported spring- and fall-run chinook salmon. Spring-run chinook salmon typically entered the American River from May through July, and fall-run chinook salmon entered the river from September through December. Between all the periods in the fall-run chinook life cycle (upstream mitigation, adult holding and egg development, spawning, egg incubation, fry emergence and rearing, juvenile rearing and emigration), this salmonoid stays in the Lower American River almost year-round (figure 2-2). It is believed that spring-run chinook salmon were extirpated from the American River (Surface Water Resources 2001a).

It has been estimated that the American River may have historically supported runs exceeding 100,000 chinook salmon annually. Population numbers fell during the 1944–1955 period primarily because of migration barriers and habitat blockage, increasing agricultural diversions, acid drainage from hard rock mining, and overfishing. Since 1955, chinook salmon populations have been augmented by hatchery operations (Surface Water Resources 2001a).

Fall-run chinook salmon, determined a candidate threatened species in September 1999 under the federal Endangered Species Act, has been the dominant run of chinook salmon in the Lower American River since the 1940s. A goal of the 1992 Central Valley Project Improvement Act is to double (from the 1967 to 1991 baseline period) the *natural production* of anadromous salmonids in the Central Valley, including the Lower American River. This goal takes into account numerous factors including commercial and sport harvest. For comparative purposes, estimated annual in-river adult chinook salmon escapement averaged 32,307 fish from 1967 through 1991, and estimated annual escapement averaged 41,933 fish from 1992 through 1999. The preliminary estimate for 2000 spawning escapement exceed 100,000 fish. Although this number is near historical levels, natural runs are still very depressed. Loss of historic habitat range due to dams, and the degradation of remaining habitat due to point and non-point pollution, elevated water temperatures and diminished flows, still leave several concerns regarding it status (Myers, et al. 1998).

Since construction and operation of the Nimbus Hatchery began in 1955, Lower American River chinook salmon runs have generally increased. Hatchery practices implemented to increase survival have contributed to this increase. A majority of the total annual spawning run was estimated to be composed of hatchery-reared fish, based on coded-wire tagging studies conducted from 1978 to 1984. However, since the hatchery tagging experiments conducted in

1978–1984, no constant marking programs have been implemented in Central Valley hatcheries. The result is a lack of sufficient data to directly determine the current contribution of hatchery-reared fish to the total Lower American River spawning population (Surface Water Resources 2001a).

Several environmental conditions influence the in-stream natural production of fall-run chinook salmon in the Lower American River. Flow, water temperature, substrate, and cover are believed to be the most important of those conditions. Flow and water temperatures have been identified as particularly critical conditions (Surface Water Resources 2001a).

Water temperature affects chinook salmon behavior. Adult chinook salmon migrate up the Sacramento–San Joaquin Delta and into the Lower American River generally from July to January. Spawning extends from as early as the beginning of October to January, and peak spawning typically occurs from mid- to late November. The timing of fall-run chinook salmon spawning is responsive to temperature changes in the Lower American River, which are affected by changes in the Folsom Dam shutter configuration and coldwater pool management. Initiation of spawning can vary by 1 month or more (early October–mid-November), depending on the prevailing water temperature regime. Relatively high water temperatures at the beginning of the fall-run chinook salmon spawning season can delay the onset of spawning in many years. Spawning typically does not occur until mean daily water temperatures decrease to about 60°F. Also, Nimbus Hatchery data suggest that percent egg fertilization rapidly increases when daily median temperatures decline below 60°F. In the last 10 years, mean daily water temperatures at or below 60°F in the upper reaches of the Lower American River typically have not occurred until the end of the first week of November (Surface Water Resources 2001a).

Water temperature can also contribute directly to the triggering of seaward migration. Water temperature moderates emigration timing by controlling the rate of growth and physiologic development of juvenile salmonids. However, because most fall-run chinook salmon emigrate from the Lower American River as postemergent fry, they require additional growth and development after leaving the river before entering the ocean if they are to attain a size conducive to survival to adulthood. Emigration timing varies from year to year but primarily occurs between late December and April. The timing of juvenile chinook salmon emigration in recent years is comparable to that observed during 1988 and 1989 but much earlier than that observed from 1945 through 1947. The signals that actually trigger emigration are similar to those that moderate the timing of emigration (i.e., flow, temperature, fish size) but occur post emergence (usually after mid-January). Brown et al. (1992) found that emigration of juvenile salmon was associated with higher flows after the emergence period. However, this positive correlation is probably reversed when flows reach higher levels. Snider et al. (1998) found that in 1994, 1995, 1996, and 1997, there was no evidence that peak emigration was related to peak winter or spring flows. In 1995, for example, most emigrating salmon were caught with flow ranged from 4,000 to 10,000 cfs, whereas maximum flow ranged from 30,000 cfs in January to 40,000 cfs in March. The relatively early emergence and emigration currently observed in the Lower American River is likely a result of the temperature-moderating effect of Folsom Lake and Lake Natoma or the different runs of chinook salmon that historically spawned upstream in the American River Basin (Surface Water Resources 2001a). Table 2-1 depicts the typical temperatures of the Lower American River during different life stages of the fall/late fall–run chinook salmon, as well as the effects of higher temperatures on those and subsequent life stages.

As with other populations of fall-run chinook salmon in the Central Valley, fall-run chinook salmon of the Lower American River have been subject to increasing ocean harvest rates over the years. However, the ocean harvest index has dropped from more than 70% from 1985 through 1995 to near 50% in the past few years. This trend, if it continues, could contribute to increases in the number of chinook salmon returning to Central Valley streams, including the American River (Surface Water Resources 2001a).

Steelhead. The Lower American River originally supported summer-, fall-, and winter-run steelhead. Summer-run steelhead typically entered the river between May and July, fall-run between September and November, and winter-run between December and April (figure 2-3). All steelhead spawning occurred upstream of what is now Nimbus Dam. By 1955, it is believed that summer-run steelhead had been extirpated from the American River, and only remnant populations of the fall- and winter-run steelhead remained (Surface Water Resources 2001a).

Central Valley steelhead are listed as threatened under the federal Endangered Species Act, and they reside within the Lower American River during stages of their life cycle. From 1956 through the late 1980s, the Nimbus Hatchery propagated eggs of steelhead strains from other locations in California and Washington, planting the fry into the Lower American River. Phenotypic expression of steelhead in the Lower American River most closely resembles that of the historic winter-run strain of American River steelhead, as well as the Eel River strain of winter-run steelhead (Surface Water Resources 2001a).

There are no comprehensive estimates available for current annual run size of American River steelhead (also known as Nimbus Hatchery strain steelhead). Staley (1976) conducted mark-and-recapture estimates for 1971–1972 and 1973–1974, providing the only estimates in relatively recent years of Lower American River steelhead run size. Carcass surveys, a method used to estimate salmon spawning populations, are not very useful for assessing steelhead spawning populations because steelhead do not necessarily die after spawning, and spawning typically occurs when streamflows are high because of winter storms (Surface Water Resources 2001a).

Since the hatchery began operation in 1995, it has provided the best available measure of steelhead run size. Hatchery counts, however, are inconsistent because Lower American River spawning steelhead were often denied access to the hatchery ponds for a portion of their spawning season (November–December). Hatchery counts can be an indication of run size, but should be used with caution because the entire hatchery escapement is not always counted (McEwan and Jackson 1996) (Surface Water Resources 2001a).

Gerstung (1985) estimated that, because of limited rearing habitat and heavy angling mortality, natural production contributed less than 5% to spawning escapement. Results of a fin-marking experiment led Staley (1976) to conclude that the hatchery was producing the bulk of the run. However, sampling conducted by DFG since 1992 has found abundant juvenile steelhead annually in the Lower American River (Snider pers. comm.). With the exception of an emergency release in January 1997 because of flooding, juvenile steelhead have not been planted in the Lower American River since 1989, indicating that the fish observed by DFG are naturally produced (Snider pers. comm.) (Surface Water Resources 2001a).

Hatchery-maintained runs of steelhead have declined since the late 1960s and early 1970s. The estimated steelhead run size in the American River in 1971–72 and 1973–74 was 19,583 and 12,274, respectively (Staley 1976). Staley (1976) estimated the steelhead harvest rate for the American River to be 27% for these 2 seasons. Assuming the harvest rate is the same, run sizes of 305, 1,462, and 255 are estimated to have occurred for the 90/91 through 92/93 seasons, respectively, based on the escapement into the hatchery (McEwan and Jackson 1996). These estimates do not include steelhead adults that are less than 20 inches long. (Staley (1976) considered all rainbow trout greater than 14 inches to be steelhead; Nimbus Hatchery counts include only rainbow trout longer than 20 inches). However, few steelhead less than 20 inches long are observed at the hatchery. Correcting for this bias, or if there is currently a harvest rate greater than 27%, will not appreciably change the current estimates; the present run size is still considerably less than it was in the early 1970s (McEwan and Jackson 1996) (Surface Water Resources 2001a).

Natural production of steelhead in the American River will continue to be limited because of inaccessibility of the headwaters. The proportion of hatchery origin fish spawning in the river remains uncertain, but it is known that the vast majority of the steelhead returning to the hatchery is of hatchery origin (Surface Water Resources 2001a).

Adult steelhead spawn primarily in the upper portion of the Lower American River above RM 16. Steelhead use the upper portion of the river for spawning to a similar extent as fall-run chinook salmon. Some steelhead spawning has also been observed below Paradise Beach (RM 5), which has not been observed for fall-run chinook salmon. Adult steelhead appear to prefer flat-water glide habitat for spawning (Surface Water Resources 2001a).

Flow and temperature conditions affect the life-stage periodicity of Lower American River steelhead. Cooler water temperatures upstream during the spring may be responsible for later steelhead emergence in upstream locations relative to downstream locations. Also, smaller average fish size in the uppermost reaches of the Lower American River after March may indicate later spawning, slower developmental rates, and later and protracted emergence because of longitudinal temperature differences (Surface Water Resources 2001a). (see Table 2-1)

Steelhead that are less than 1 year old (young of the year [YOY]) begin to appear in rotary screw traps in mid-January (1997) at the earliest, but more typically appear in mid-March. YOY steelhead typically begin to appear in seining surveys, however, before mid-March. The earlier appearance of YOY steelhead in seining surveys suggests that emergence and emigration are not necessarily coincident. Despite rotary screw trap catches of YOY steelhead, it appears that few steelhead, if any, actively emigrate as YOY (Surface Water Resources 2001a).

Yearling steelhead typically appear in the rotary screw traps during winter before March, somewhat earlier than YOY. The presence of apparent in-river–produced yearling fish in February and March strongly suggests some over-summer survival, but the origin of these fish is uncertain. The presence of YOY steelhead in October also indicates over-summer survival. Yearling fish catches in fall and winter may indicate, however, that YOY steelhead spend summers outside of the Lower American River and return during late fall and winter (Surface Water Resources 2001a).

Summer water temperature appears to be the most important stressor affecting steelhead because steelhead rear throughout the year in the Lower American River. Summer water temperatures frequently exceed those reported as suitable for juvenile steelhead rearing (Surface Water Resources 2001a). Table 2-1 depicts the typical temperatures of the Lower American River during different life stages of the steelhead, as well as the effects of higher temperatures on those and subsequent life stages.

Early YOY rearing occurs primarily proximal to spawning areas in upstream areas of the Lower American River. By late summer, YOY steelhead are distributed throughout the Lower American River and exhibit site fidelity (returning to the same spot for spawning). Limited mark and recapture evaluations of juvenile steelhead collected by seining in the Lower American River since 1996 indicate that juveniles tend to occupy specific habitats throughout the summer. Yearling steelhead are found in bar complex and side channel areas characterized by habitat complexity in the form of velocity shelters, hydraulic roughness elements, and other forms of cover. Larger fish typically inhabit fast-water areas such as riffles (Surface Water Resources 2001a).

Water Quality

Current water quality does not appear to be a major stressor affecting fish populations in the Lower American River. In general, ambient water quality characteristics meet applicable regulatory standards, but occasional exceedances for toxicity, selected heavy metals, coliform, chlorpyrifos, and diazinon exist. Generally, concentrations of contaminants increase downstream from Nimbus Dam to Discovery Park (Surface Water Resources 2001a).

Groundwater contamination exists below the Lower American River. The highest concentrations and widest distribution of chemicals are found in the middle of the 3 aquifers lying below the Lower American River. Concentrations of trichloroethylene (TCE) are also found in the upper aquifer bordering the Lower American River. However, Aerojet groundwater contamination does not currently appear to pose a water quality threat to fish resources in the Lower American River (Surface Water Resources 2001a).

Recreation

One of the primary purposes of the American River Parkway is to provide recreation and open space resources for the residents of Sacramento County and surrounding areas. A wide variety of recreation and open space resources exist within the Parkway, including: a 26-mile paved Jedediah Smith Memorial Bicycle Trail, a parallel unpaved equestrian trail, boat ramps and car-top boat launch areas, fishing areas, developed parks and picnic sites, golf courses, interpretive centers, restrooms, access roads, nature study areas, and protected habitat areas.

The federal and state Wild and Scenic Rivers Acts designate that certain rivers that possess extraordinary scenic, recreational, fishery, or wildlife values shall be preserved in their free-flowing state for the benefit and enjoyment of people as well as to protect the water quality of such rivers and to fulfill other vital national conservation purposes. The Lower American River is the central focus of the Parkway and is the most heavily used recreational river in California. The Lower American River was included in the federal and state Wild and Scenic Rivers systems because of some or all of its fisheries, wildlife, scenic, and recreational values, but primarily because of its recreation and anadromous fishery values.

2.1.4 Future Without-Project Conditions

SAFCA and the Bureau executed an interim reservoir operations agreement in March 1995. This agreement requires SAFCA to fund additional modifications to the temperature control shutters at Folsom to improve the Bureau's ability to manage Folsom's coldwater pool. In March 1995, these shutters were configured in a 1-1-7 arrangement that constrained management of the coldwater pool. Under the interim agreement, SAFCA provided funding for the Bureau to redesign and reconfigure the shutters into a 3-2-4 arrangement. This modification measurably improved the Bureau's ability to manage Folsom's coldwater pool and more than offset any adverse impacts on Lower American River fisheries that might have resulted from the conditions outlined in the interim agreement. In order to offset any temperature-related impacts that might otherwise result from extending the variable-space storage option at Folsom, the extended agreement requires SAFCA to fund the design and construction of a 1-1-2-2-3 shutter configuration that would allow the Bureau even more ability to improve temperature conditions for Lower American River fisheries (Jones & Stokes 2000). Such a configuration would allow for selection of six different release elevations instead of the historical two or four. This configuration would be operated manually.

The Bureau operates the American River Division of the Central Valley Project under a biological opinion with NMFS to meet, to the extent possible, the temperature objectives for the Nimbus Fish Hatchery and the American River Trout Hatchery, while maintaining suitable temperatures for instream salmonids. The interagency American River Operations Group (the Bureau, FWS, NMFS, DFG, Sacramento County, and Save the American River Association) was created in 1996 and assists the Bureau to adaptively manage releases and water temperature conditions on the lower American River to meet the needs of fall-fun Chinook salmon and steelhead within the river.

The Bureau is currently implementing a short-term measure of more frequent shutter changes as a short-term solution. This measure is intended to reduce water temperatures until construction or implementation of a long-term operational or structural measure can be accomplished. The implementation of more frequent shutter changes is dependent upon time and manpower of the Bureau's staff. It is anticipated that this program would continue under the future without-project condition. It is anticipated that the future without-project condition would provide greater flexibility in release elevations and therefore, allow more efficient use of available coldwater pool in Folsom Reservoir. Improved temperature management will likely result in the ability to reduce temperatures in the Lower American River during critical life stages of native fish populations. Reduction in temperature results in an increase in suitable spawning habitat and the potential for an increase in overall natural production of native fishes.

2.1.5 Other Planning Efforts

Several key local, state, and federal legislation and planning efforts relevant to the Lower American River could affect or influence this aquatic ecosystem restoration plan. Key planning efforts include the American River Watershed Investigation Feasibility Report, American River Long-Term Watershed Investigation, River Corridor Management Plan (RCMP) for the Lower American River, Floodway Management Plan (FMP) for the Lower American River, the American River Parkway Plan (ARPP), Lower American River Task Force, and Cal Expo Master Plan. These plans, planning efforts, and legislation are summarized below.

American River Watershed Investigation Feasibility Report. The purpose of this report was to conduct planning-related studies that could lead to future flood protection improvement for the Sacramento area. The studies lead to the development of 4 different alternatives; 1 was eventually selected for implementation. The principal recommendations of this plan were to build a detention facility on the North Fork American River near Auburn and to improve levees and channels in the Natomas area. No direct alternatives were recommended for the Lower American River between Nimbus Dam and the confluence with the Sacramento River. This report was amended in 1996.

Supplemental Information Report, American River Watershed Project, California. This study supplemented the December 1991 feasibility report for the American River Watershed Investigation. The report reassesses the risk to the Sacramento area of flooding from the American River as well as reassesses individual flood protection measures to reduce the risk. A range of alternatives, including combination of the individual measures is also described. The report presents three candidate flood protection plans and identifies the locally preferred plan, which is also the federally "selected plan." The process for implementing the selected plan and important future actions is also described. The report has two parts: a main report, focusing on the flood protection alternatives, and a supplemental environmental impact report. This report was requested by Congress and reflects information and comments from extensive review by both the public and governmental agencies. This report resulted in levee system improvements.

American River Watershed Long-Term Study. This study addresses proposed alternatives for a comprehensive solution to flood control problems in the Sacramento Area, and ecosystem restoration at selected sites along the Lower American River. The study is part of the federally authorized American River Watershed Project. The 2 classes of flood control alternatives are modifying levees to increase American River conveyance capacity through Sacramento and increasing flood control storage through enlargement of Folsom Dam and Reservoir. This study supplements the American River Watershed Project described above, and the 1991 Feasibility Report for the American River Watershed Investigation. The study includes:

- a supplemental inventory and forecast of existing and future conditions in the study area;
- background information on flood problems and potential solutions in the Sacramento area;
- text describing the formulation and evaluation of the alternative pans, along with a comparison of the plans;
- current information on the costs and benefits of Folsom Dam enlargement and downstream levee modification measures and plans; and
- updated cost and benefit information on the previously considered upstream detention dam.

Lower American River Task Force. The Lower American River Task Force is a collaborative forum created by SAFCA in 1994 to improve existing flood control facilities while protecting and enhancing the Lower American River's environmental and recreation resources. The task force's current effort is developing a river corridor management plan (RCMP), which is intended to serve as an overarching vision, or blueprint, for the river. The RCMP promotes a cooperative approach to managing and enhancing the Lower American River in the framework of the 1985 ARPP. In addition, the RCMP is intended to serve as a catalyst for updating the ARPP so that decision makers can strengthen its resource management provisions, address important land use- and recreation-related issues, and refine existing Parkway management mechanisms as necessary to give appropriate status to the cooperative relationships that have developed over the past 7 years through the task force and the water forum. In the process of developing the RCMP, the stakeholder base was broadened, and technical working groups were formed to address particular elements of the plan. There are four working groups: recreation, bank protection, FISH, and floodway management. Each working group is working to develop the technical sections to be included in the RCMP. Much of this document will build on existing studies, including the aforementioned studies and the DFG's Steelhead Restoration and Management Plan for the Lower American River and the U.S. Fish and Wildlife Service's Anadromous Fish Restoration Program (Jones & Stokes 2001).

Floodway Management Plan for the Lower American River. The FMP is a collaborative effort spearheaded by SAFCA to solve the physical problems of the Lower American River flood control system. A critical aspect of the FMP is that the needs of the flood control system are balanced with the needs of other competing resources, including fishery and aquatic habitats, terrestrial habitats, and recreation and open space resources. A primary concern of the FMP is maintaining an acceptable level of flood protection in the Sacramento metropolitan area. In addition, the FMP addresses the following:

- aquatic and terrestrial habitat management and restoration as they relate directly to floodway management,

- recreation and open space protection and enhancement by increasing availability and reducing the impacts that floodflows have on these community resources, and

- fire management consistent with meeting other resource needs.

Recommendations in the FMP, in part, led to the development of the RCMP.

Recreation Planning. In addition to the recreation planning being undertaken by the Recreation Working Group as a part of the RCMP, 2 additional trails in the planning stages would tie into the American River Parkway. The Corps and City of Sacramento, with assistance from Jones & Stokes, are preparing construction documents for the Ueda Parkway, a multiuse trail adjacent to the Natomas East Main Drainage Canal connecting the Jedediah Smith Memorial Trail to communities to the north. The City of Sacramento is also engaging in conceptual planning for the Two Rivers Trail that will run from the new Sutter's Landing Park (at the site of the old city landfill) along the south bank of the American River to the confluence with the Sacramento River.

American River Parkway Plan. The first ARPP was produced in 1962. It was revised in 1968 and 1976 with significant public input. The current version was published in 1985. The ARPP calls for evaluation and revision, if necessary, every 5 years. The American River Parkway Plan is an element of both the City of Sacramento and County of Sacramento General Plans and has been adopted by the State Legislature. An effort to update the plan is beginning and likely will be led by the Sacramento County Department of Parks, Recreation, and Open Space. The goals of the Parkway plan are to:

- provide, protect, and enhance for public use a continuous open space greenbelt extending from the Sacramento River to the Sierra Nevada;

- provide appropriate access and facilities so that present and future generations can enjoy the amenities and resources of the Parkway;

- preserve and improve the natural, archeological, historical, and recreational resources of the Parkway, including an adequate flow of high-quality water, anadromous and resident fishes, migratory and resident wildlife, and diverse natural vegetation; and

- mitigate adverse effects of activities and facilities adjacent to the Parkway.

Only current, comprehensive studies are indicated here. There are many other important resource-specific studies that have been prepared. Additional agency programs and colleges and universities are continuing to investigate individual wildlife, fish, and vegetation issues as they pertain to the Lower American River corridor.

SECTION 3.0

PLAN FORMULATION

Under Corps guidelines, the purpose of ecosystem restoration is to restore significant ecosystem function, structure, and dynamic processes that have been degraded. The intent of restoration is to reestablish the attributes of a naturalistic, functioning, and self-regulating system. The formulation of this plan focuses on this stated purpose and intent. The project team evaluated several different measures for reconfiguring current structures or implementing the construction of new structures to facilitate optimum management of water temperature in the Lower American River.

3.1 Restoration Goals

The FISH Working Group, 1 of the 4 working groups of the Lower American River Task Force, commissioned the preparation of a report, the Baseline Report, that would outline baseline conditions within the Lower American River with respect to aquatic habitat. The Baseline Report provided the basis for prioritizing opportunities for restoration of aquatic habitat in the Lower American River. The Baseline Report established that flow and temperature improvements have the greatest potential for restoration with respect to the fish of primary management concern. As a result, the most immediate opportunities that exist for fish habitat improvement involve hydrologic system operations and management actions. Manipulating the timing, temperature, and rate of flow released from Folsom and Nimbus Dams is likely to produce the most immediate and effective results for fish restoration (Surface Water Resources 2001a).

An adequate flow and water temperature regime is essential to create favorable conditions for Lower American River salmonids. Streamflow patterns are important in maintaining geomorphology of watersheds such as meander belts and stream channel configuration, as well as riparian and floodplain vegetation along stream banks. Streamflow influences the well-being of valley wetlands, riparian communities, and the habitat of fish and other aquatic organisms. Streamflow also is essential for the well-being of native resident fish, including anadromous salmonids. Sufficient flows are necessary for anadromous salmonid adult migration, spawning, egg incubation, and juvenile rearing and emigration especially because these functions must now occur in the lowermost 23 miles of the American River below Nimbus Dam. In some cases, flows exceeding natural, unimpaired river flows below Nimbus Dam are recommended because anadromous salmonids must conduct these functions in the nontraditional habitats of the lower river instead of the upstream reaches above the present dam sites (Surface Water Resources 2001a).

Of all limiting factors and potential corrective actions, maintaining suitable water temperatures and instream flows will be more beneficial for salmonid production in the Lower American River than all other actions combined. As noted previously in the introduction, flow standards are under development by the Water Forum effort and will address the needs for adequate flows. Therefore, building on the baseline conditions and prioritization summarized in the Baseline Report prepared for the FISH Working Group, the following goals have been established for the management and restoration of water temperature in the Lower American River below Nimbus Dam:

Goal 1: Reduce water temperature in the Lower American River during critical stages in the life cycles of fall-run salmon and steelhead so as to increase the number of these fish spawning naturally in the river.

Goal 2: To the greatest extent possible, reach those temperatures recommended by the DFG for winter-run Central Valley steelhead and fall/late fall–run chinook salmon (i.e., 56°F between October 1 and June 30 and between 56 and 60°F for July 1–September 30).

Goal 3: Significantly increase the fall-run chinook and steelhead natural production fish populations in the Lower American River. This goal is in line with the policy of the Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 to double the natural production of salmon and steelhead by the end of the last century.

3.2 Restoration Objectives

Based on the aforementioned goals, objectives were developed to complement and provide focus to these goals. Some objectives are applicable to more than one goal.

Objective 1: Improve Adult Migration.

Elevated temperatures in late summer and early fall in the Lower American River (sometimes extending well into October) often exceed 65ºF. Relatively high water temperatures delay the onset of adult fall-run chinook salmon spawning and impede reproductive success. Exposure of prespawning adult chinook salmon to relatively high water temperatures can result in increased prespawning mortality, reduced gamete production, infertility, and increased embryonic developmental abnormalities.

Objective 2: Increase Spawning Habitat.

Chinook salmon spawning is concentrated in several well-documented areas in the river, primarily between RM 14 and 22. During low-flow conditions and high-temperature conditions, the extent of available spawning habitat is further restricted. Adult fall-run chinook salmon generally do not initiate spawning in the Lower American River until water temperatures decrease to approximately 60°F.

Objective 3: Reduce Egg Mortality.

Constant exposure of salmonid eggs to temperatures above 56°F will result in some egg mortality, and incubation at constant water temperatures above 63°F is believed to result in complete egg mortality. Temperatures above 56ºF can occur when eggs and alevins are incubating in the Lower American River. This problem is most likely to occur for chinook salmon in October and November.

Objective 4: Improve Rearing Habitat and Juvenile Outmigration.

The availability of rearing habitat is directly related to flow; however, physical habitat availability considerations are probably overridden by water temperature concerns during late spring, summer, and early fall. In addition to direct thermal stress, elevated chinook salmon and steelhead rearing and outmigration temperatures can result in multiple indirect effects, including increased risk of predation, decreased growth rates, starvation, and susceptibility to disease, which contribute to reduced juvenile survival. Thermal stress to juvenile steelhead is a particular problem from July through October, when water temperatures at Watt Avenue frequently exceed 65°F.

3.3 Planning Constraints

Consideration was given to several planning constraints during development of the goals, objectives, and measures:

- Proposed restoration activities will be consistent with the RCMP.
- Existing high-quality wildlife habitat, fisheries habitat, and native plant communities will not be disturbed by restoration activities.
- American River Parkway recreation activities will be maintained.
- Existing major utility, gas, sewer, cable, and telephone infrastructure will remain in place and access maintained.
- The flood capacity of the floodway will be maintained.
- Proposed restoration activities will be self-sustaining, requiring little long-term maintenance.
- Generation of hydroelectric power at Folsom Dam water supply will be maintained.
- Boating and other recreation on Folsom Reservoir and Lake Natoma will be maintained.

The following section evaluates measures that could be implemented to achieve the aforementioned goal and objectives, while considering the planning criteria and constraints.

3.4 Planning Criteria

Structural and operational temperature reduction measures were screened to identify a preferred temperature restoration measure. Alternatives were screened by using the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) identified in the Corps' *Planning Manual* (U.S. Army Corps of Engineers 1996). The Corps' four standard Principles & Guideline screening criteria used for this analysis include:

Effectiveness: *The extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.* An effective plan is responsive to the wants and needs of people and makes a significant contribution to the solution of some problem. Measures that make a significant contribution to the planning goals were advanced.

Efficiency: *The extent to which an alternative plan is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment.* Efficiency measures not only evaluate dollar costs, but also evaluate whether other resources are used efficiently in the construction and implementation of a plan; this is represented as "cost-effectiveness." Only cost-effective measures were advanced.

Acceptability: *The workability and viability of the alternative plan with respect to acceptance by State and local entities and the public and compatibility with existing laws, regulations, and public policies.* The two primary components of acceptability include implementability, including technological, environmental, economic, and social feasibility, and satisfaction. Measures that were readily implementable and satisfactory to the Corps, the Bureau, and FISH Work Group were advanced.

Completeness: *The extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.* Measures that were well thought out and whose implementation actions are accounted for in context of all investments and actions were advanced.

These criteria were applied to the alternatives analysis discussed in Section 4 below.

SECTION 4.0

RESTORATION MEASURES EVALUATED

A number of restoration measures were evaluated to determine which would most appropriately achieve the fisheries/aquatic restoration goals given a number of different screening criteria. Measures are direct actions taken to achieve the restoration goals and objectives. This section describes the rationale for selection of measures; describes the measures, the screening process, and qualitative impact analysis; and identifies a preferred restoration measure. Much of the information in this section comes from the Bureau's Lower American River Temperature Improvement Study Function Analysis Workshop, dated January 2001.

4.1 Rationale for Selection of Measures and Criteria

4.1.1 Development of the Measures

The Bureau conducted the Lower American River Temperature Improvement Study Function Analysis Workshop to identify, evaluate, and recommend solutions to provide optimum water temperatures in the Lower American River for improving anadromous fish spawning. The 4 major components of this effort were to:

- provide an independent review of previously identified Lower American River temperature improvement alternatives;
- identify other water-related problems/constraints and potential solutions;
- evaluate alternatives with regard to costs, regulatory constraints, advantages/disadvantages, prior accomplishments, and future conditions; and
- provide viable recommendations for temperature optimization in the Lower American River.

Workshop participants were divided into 3 work groups: the Folsom Reservoir and Headwaters work group, the Lake Natoma/Nimbus Dam work group, and the Nimbus Hatchery and Open Lower American River work group. Each work group was charged with developing a problem statement and identifying solutions to address the problem statement. The Folsom Reservoir and Headwaters work group identified the problem as inefficient storage and management of the coldwater pool in Folsom Lake. The Lake Natoma/Nimbus Dam work group identified the problem as inefficient transport of cold water through Lake Natoma and Nimbus Dam. The Nimbus Hatchery and Open Lower American River work group identified the problem as extending coldwater habitat downstream on the Lower American River on a year-round basis. The temperature restoration measures evaluated in this report are a result of the proposals advanced as part of the workshop, interviews with engineers and biologists knowledgeable in temperature control techniques, and a review of basic temperature control literature.

4.1.2 Screening Process and Qualitative Impact Assessment

The Corps' 4 standard planning screening criteria, including effectiveness, efficiency, acceptability, and completeness as outlined in Section 3, are used for this analysis.

A tabular evaluation of the restoration measures can be found in table 4-1. In general, the operational fixes are short-term and less expensive but deliver less temperature benefit. The structural measures are more expensive, but deliver more thorough and reliable benefits. Each measure is described and evaluated below.

4.2 Description and Evaluation of Measures

The following 24 measures, 15 structural, 8 operational, and 1 combination measure, were considered when screening alternative temperature-reduction measures. The Folsom Lake and Headwaters work group provided the following structural and operational measures to reduce water temperatures in the Lower American River:

- modernizing the shutters to a 7(1)-2 configuration,
- installing temperature curtains at tributary inflows,
- installing or using low-level outlet works to generate power and access coldest water in the lake,
- constructing a cold-water isolation/pump back system to exchange water between Lake Natoma and Folsom Reservoir,
- retrofitting the shutters with an "elephant trunk" that delivers cold water to the penstock,
- improving the short-term management of shutter operation,
- conducting additional temperature monitoring,
- purchasing water from upstream reservoirs to increase the supply of cold water in Folsom Reservoir,
- normalizing gate operations (to mimic natural hydrology), and
- bypassing the turbines and releasing directly from the low-level outlet works.

The Lake Natoma/Nimbus Dam work group provided the following structural measures to reduce water temperatures in the Lower American River:

- installing temperature curtains (either at the plunge zone of Lake Natoma or at the Nimbus Power Plant intake),
- removing all, or part of, the submerged concrete debris wall in front of the Nimbus Power Plant,
- constructing a temperature control device for Nimbus Dam Spillway Bay(s),
- modifying the channel in Lake Natoma,
- installing a pipe from Folsom Tailrace to Nimbus outlet,
- moving Natoma Power Plant and outlet to the opposite side of Lake Natoma with a temperature control device, and
- placing a coldwater barrier in front of Folsom South Canal.

The Nimbus Hatchery and Open Lower American River work group provided the following structural and operational measures to enhance fish habitat:

- building instream habitat improvement projects downstream of Nimbus Dam,
- developing access for steelhead above Folsom Dam,
- building off-site habitat downstream of Nimbus Dam for steelhead,
- improving real-time temperature monitoring,
- diverting flows from Folsom South Canal into the Cosumnes River,
- performing a quick evaluation of current operations, and
- coordinating techniques and tools to optimize use of cold water.

Each structural and operational technique is described in more detail below. Some measures are removed from consideration because they do not meet the fisheries/aquatic restoration goals and objectives of this project; however, excluded measures may be considered as part of other projects or restoration efforts.

4.2.1 Measure 1: Modernize Shutters

Background

On Folsom Dam, temperature shutters are the screens that regulate the inflow of water into the 3 power-generating penstocks, specifically the water level from which flow is received. As such, manipulation of the shutters comprises the temperature control device. Modernizing the shutters would serve to improve the efficiency and operation of the penstock.

Folsom Dam shutter management currently allows some flexibility in the management of the coldwater releases from the reservoir. By operating the shutters to withdraw water from the highest available reservoir elevation during winter and spring, when water temperature are suitably cold for fishery protection, the lowest reservoir elevation coldwater reserves can be conserved for later seasonal fishery protection benefits. During the thermal fishery protection seasons, generally summer and fall, temperature control shutters are managed to withdraw from reservoir elevations in a manner that best matches the capabilities of the selective shutter operations and fishery protection objectives. (Surface Water Resources 2001b.)

Each of the 3 power penstock intakes on Folsom Dam is enclosed in a housing that supports a set of removable shutter panels. Each penstock intake's housing supports a set of 45 panels assembled in 5 vertical sets of 9 panels. Each panel is 13 feet high. The penstock intakes are located low inside the shutter assembly. Varying numbers of panels can be lifted to draw in water from various elevations, thereby controlling the temperature of the water released from Folsom Dam. Historically, the temperature control shutter panels have been bolted together in 2 configurations to comprise each group of 9: 1-1-7 and 3-2-4 (figure 4-1). In the 1-1-7 configuration, the top 2 panels could be raised individually and the remaining 7 lower panels were bolted together and could be raised only as a unit after the top 2 panels were raised. In the existing 3-2-4 configuration, the top 3 panels are bolted together and can be raised as a unit, followed by the next 2 panels as a unit and then the remaining 4 panels as a unit. These configurations allowed for 4 distinct elevations from which the releases from Folsom Dam could be drawn. Units of shutter panels can be removed or replaced allowing releases to be made without any panels in place, or with the lowest, 2 lowest, or all 3 units in place. The structure of the Folsom Dam shutter housing currently limits the number of shutter panel units to 3.

A current reconfiguration proposal exists that would result in a future without-project configuration of 1-1-2-2-3. This configuration is required for mitigation of the SAFCA–proposed reoperation of Folsom Reservoir. Although, this configuration would be an improvement over the existing condition, it does not allow for maximum operational flexibility and optimization of coldwater releases.

Shutter position changes at Folsom Dam are currently performed manually. A crew of 3 people—1 to operate the gantry crane trolley beam and hoist, 1 to check operations and signal the crane, and 1 to set latches, pull pins, etc.—is required to change the shutter positions. The operation requires 8–12 hours to adjust all shutter groups and occasionally interferes with traffic using the road across the dam depending on whether the crane must be repositioned. Because of the manual labor requirements, shutter changes must be scheduled approximately 2 weeks in advance. The current configuration is changed 3–4 times per year. (Surface Water Resources 2001b.)

Description of Action

The proposed modernization of the Folsom Dam shutters would consist of structural changes to the current shutter configuration. The proposed configuration is 1-1-1-1-1-1-1-2 [i.e., 7(1)–2] (figure 4-2). Modifying the structure to this configuration would improve the ability to release from various levels in Folsom Reservoir by allowing each structure to be raised and lowered individually. The bottom 2 shutters would have to be operated as a single unit because of flow limitations. The cost of implementing this proposed modernization is approximately $9 million–$20 million.

Evaluation

Modernizing the temperature shutters on Folsom Dam would result in the ability to regulate temperature releases from Folsom Dam and would provide the dam operator with an opportunity to respond to monthly, weekly, or daily temperature fluctuations. There are several possible ways to modify the structure, as described section 5, that provide varying levels of operational flexibility. The shutters are currently proposed for modernization, but additional modifications would increase the operational flexibility of this measure. This measure would be highly effective at using the cold water in Folsom Reservoir and ensuring the delivery of cold water to the Lower American River.

Although this measure is moderately expensive, it is one of the least expensive structural fixes and has the potential to result in the greatest benefits. Annual amortized costs for this type of structure range would vary depending on final project costs.

This structural approach provides for increased and more accurate control of water temperatures and is the most workable, viable, and reliable of all structural measures considered. It is a direct fix that eliminates “stair-step” temperature fluctuations and allows for incremental temperature changes that maximize the conservation of cold water in Folsom Reservoir. It is superior to the future without-project condition of 1-1-2-2-3 in operational flexibility and ability to meet the quantitative objectives for temperature. This measure would also result in the fewest impacts on other resources such as power generation, environmental resources, safety, recreation, and water supply. Power generation can continue unimpeded. Negative environmental impacts anticipated from construction of the modernized shutters would be avoided by constructing during non-critical-temperature times. There are no negative environmental impacts anticipated from operation of modernized shutters. Recreational uses would continue unimpeded. There would be no impact on overall water supply. This measure would be acceptable because it can be implemented and is satisfactory for the reasons described above.

Depending on the type of modernization, manual or mechanized, the shutters could be easier to operate and could minimize potential traffic effects. These approaches are described in section 5.

Modernization of the shutters on Folsom Reservoir is a complete measure. It maximizes the use of previous capital investments by modifying the existing structure and making use of the penstock facilities. It also has the greatest opportunity to realize the planned effects of reduced downstream temperatures because it maximizes the use of the cold water pool in Folsom Reservoir.

This measure was carried forward for additional screening as described in section 4.3.

4.2.2 Measure 2: Install Temperature Curtains at Tributary Inflows

Background

Temperature curtains, which are devices that separate the thermoclyne in lakes and reservoirs, and direct flowing water to the desired levels, are not currently used on Folsom Reservoir or Lake Natoma, but they are used at other reservoirs throughout California and the western United States. Temperature curtains are available in a variety of shapes and sizes and are typically sized to meet the design goals and objectives for the site at which they are used.

Description of Action

This restoration measure would involve the construction of temperature curtains at the tributary inflow locations (i.e., the North and South Forks of the American River). The curtain would be supported through the installation of permanent lake-bottom anchors, and surface stabilizing tanks on both the upstream and downstream sides of the curtain. Bottom-retrievable weighted tanks on the curtain bottom keep it in place. A boat passage lock would be constructed in the center to allow recreational boat passage through the curtained area. During warmer tributary flows, the curtain bottom would be floated. The construction of these types of curtains could force available cold water entering the Folsom Reservoir to the deeper area of the lake where it could remain cold while flowing to Folsom Dam (figure 4-3.) The curtain could be deployed in a few days, but would need to be moved as the reservoir recedes and during the winter so it is not damaged by debris carried down the rivers during storms. The approximate cost of temperature curtains on both the North and South Forks of the American River is $2.3 million (Edwards pers. comm.). These costs are based on assumed 800-foot and 600-foot curtains, inflated Lewiston curtain costs in 2001 dollars, 25% contingency, 12% planning engineering and design, and 8.5% supervision and administration.

Evaluation

The installation of a temperature curtain is not certain to provide needed temperature reductions. Actual temperature benefits from this measure are predicted, but modeling would need to be conducted to determine the amount of cold water that is preserved in Folsom

Reservoir as a result of this project. To calculate the magnitude of the potential temperature benefits associated with construction of curtains at the tributary, a 3-dimensional model would be needed to simulate the propagation of flow and temperature through Folsom Reservoir. Furthermore, downstream releases of cold water are still needed to ensure that water temperatures at Watt Avenue are reduced. As with all structural and operational measures, if it is operated incorrectly or during the wrong temperature regime, this measure could result in lake warming. This measure could actively increase the coldwater pool at Folsom, but it is a passive way of reducing downstream temperatures because it is based on seasonal runoff and constrained by shutter operations.

While the cost associated with this action is relatively low for a structural measure, ongoing operation and maintenance costs could escalate because of vandalism and because the structure would need to be moved as the lake recedes. Additionally, the cost provided does not include replacement costs for the fabric curtain, and fabric would need to be replaced every 5 to 10 years.

Overall, this measure is not anticipated to be acceptable to the public because it could result in negative recreational and safety effects. A temperature curtain would require the creation of additional boat speed controls and would restrict boat movement across the curtain. There would be provisions for boat access, but this access would be restricted to “locks” that are built into the curtain. Boaters unfamiliar with the new structure could collide with the structure resulting in reduced boater safety in the vicinity of the curtain, as well as damage to the structure. Although the extent of environmental effects is unknown, the effects that are anticipated from this measure include increased turbidity from the movement of the curtain and removal of some shoreside vegetation from the storage and movement of the curtain. A temperature curtain would not alter power generation or water supply.

This measure was eliminated from further consideration because its overall effectiveness in reduction of water temperatures at Watt Avenue is unknown, because it would not likely be acceptable to the public, and because more information is needed to determine the investments and actions necessary to make this measure a success.

4.2.3 Measure 3: Access Low Elevation Coldwater Pool with Generation—Economically Use Coldwater Pool below Penstock Intakes

Background

The existing low-level outlet works are used in emergency flood situations to draw down lake levels. These outlet works do not flow through the power generation plant; therefore, power generation is reduced.

Description of Action

The proposed measure would involve the use of an existing outlet or the construction of a new outlet to produce power while accessing the low-level coldwater pool in Folsom Reservoir for temperature reduction downstream. A cross section of Folsom Dam (figure 4-4) shows the 4 areas where water is conveyed through the dam: the water supply intake, power penstock intake, upper river outlet, and lower river outlet. The river outlets are typically used only during large flood events when the reservoir needs to be lowered quickly. However, the depth of these outlets creates an opportunity to use the coldwater pool within Folsom Reservoir. By modifying these outlets to include a power plant or constructing a new outlet with an associated power plant, the Bureau could simultaneously release cooler water and generate power. This would enable power production while releasing water from lower levels than from the existing power plants. The cost of this restoration measure is estimated to be $90 million (Melovic pers. comm.).

Evaluation

The installation of a new low-level outlet works with power-generation facility would likely be effective at lowering water temperatures in the Lower American River. By taking water from an elevation below the existing penstock, cold water would serve to meet power generation and environmental requirements. However, this measure is one of the most expensive structural measures. The cost of this measure is largely a result of the extensive engineering and construction requirements. This type of structure was considered as part of the River Outlet Modification Project but was eliminated at that time because of cost. While there are virtually no impacts on other resources, this measure was eliminated from further consideration because it was not deemed efficient or acceptable.

4.2.4 Measure 4: Develop Coldwater Isolation/Pump Back System

Description of Action

This restoration measure involves releasing cold water from Folsom Reservoir through a newly constructed 12-foot-wide penstock on the left descending side of Folsom Dam. The penstock would continue approximately 7 miles along the shoreline of the Lower American River to a new pump generating plant just north of California State University Aquatic Club. This measure would enable isolated coldwater releases from Folsom Reservoir, subsequently reducing daily temperature peaks of water released from Nimbus Dam. Conversely, during a peak hydrologic event, warm water released into Lake Natoma from Folsom Reservoir could be pumped back into Folsom Reservoir. Through the use of the newly installed temperature control device, this water could be placed atop Folsom Reservoir to maximize conservation of the coldwater pool (figure 4-5). Essentially, this measure would provide cold water to the Nimbus powerhouse at Nimbus Dam and hatchery while recirculating warm water from Lake Natoma back to Folsom Reservoir. The cost of this restoration measure is estimated to be greater than $90 million.

Evaluation

The development of a water exchange system between Lake Natoma and Folsom Reservoir would likely result in lower water temperatures in the Lower American River, including temperatures at Watt Avenue, but the concept is still an engineering design theory and therefore technologically uncertain. In addition, pumping warm water from Lake Natoma to Folsom Reservoir would result in a 3- to 5-degree temperature increase in the pump-back water and could partially offset the benefits of the project (Melovic pers. comm.). Because of the extensive construction required, this is the most expensive structural measure. Although this measure would result in increased power generation and would not adversely affect other resources such as safety or water supply, this measure could adversely affect other environmental and recreational resources. The construction of a 7-mile pipeline would result in adverse effects on vegetation and water quality and temporary adverse construction effects on recreational uses near construction areas, therefore resulting in lower social feasibility and satisfaction. Without more detailed analysis of the investments and other actions required to realize planned effects, this measure is currently incomplete. This measure was eliminated from further consideration based on effectiveness, efficiency, acceptability, and completeness.

4.2.5 Measure 5: Install "Elephant Trunk" on Folsom Dam

Background

An elephant trunk is an intake structure that permits deeper level withdrawal of reservoir water for release through the penstocks of the dam structure. Its name is descriptive of its shape in profile.

Description of Action

This restoration measure proposes the installation of 1 or 3 elephant trunks consisting of corrugated metal pipe, to the penstocks on Folsom Dam. The structure(s) would include a steel box affixed to the bottom 2 shutter panels on the penstock(s) and connect to a 20-foot-diameter corrugated metal pipe that would extend to the lower depths of the Folsom Reservoir beneath the levels of the current shutter configuration (figure 4-6). The cost associated with the construction of 1 elephant trunk would be approximately $752,000 and 3 elephant trunks would be approximately $4 million. The increment cost for the second and third penstocks increase the overall price substantially because more materials and additional intake boxes would be needed. (Edwards pers. comm.). These costs are estimated using 2001 materials rates,; 25% contingency; 12% for planning, engineering, and design; and 8.5% for supervision and administration.

Evaluation

The installation of an elephant trunk to the penstock is a structural measure that would result in the delivery of cold water to the penstock, therefore allowing the delivery of cold water to the Lower American River. However, because of the limited volume of water conveyed through 1 penstock, 1 structure by itself would be unable to achieve downstream temperature objectives. Furthermore, 1 elephant trunk would limit reservoir operational flexibility and possibly reduce power generation because the temperatures at the penstock intakes must be the same to ensure matching temperatures after power generation. Three elephant trunks would need to be constructed to effectively achieve the temperature objectives and maintain constant power generation.

While this measure is fairly cost-effective, it is uncertain whether it is technologically viable. The flow of water up multiple large diameter elephant trunks has not been tested and may require additional mechanical assistance. A temperature control device or flow gate would be needed to regulate the water entering the trunk, and maintenance of and access to the intake of the trunk would be extremely difficult (Sanford pers. comm.). The elephant trunks would terminate near the enlarged river outlets and could experience increased sedimentation. Operation of the elephant trunks could then result in increased suspended sediment downstream of Folsom Dam. Without more detailed analysis of the investments and other actions required to realize planned effects, this measure is currently incomplete. Therefore, this measure was eliminated from further consideration.

4.2.6 Measure 6: Improve Short-Term Management of Shutter Operation

Description of Action

The proposed short-term management of shutter operations would entail frequent changes to the current shutter configuration to reduce the stair-step changes in river temperature currently experienced. More frequent changes would result in gradual changes of river temperature and blending of available water supplies. This measure is a short-term measure intended to reduce temperatures until construction or implementation of a long-term operational or structural measure. This management operation would assume that time and manpower would be made available as needed to accomplish the frequent shutter configuration changes.

In 1999, estimated annual costs for changing the shutter configuration 3 times annually were approximately $5,508 (White pers. comm.). Under the future without-project condition, the shutters will be reconfigured approximately 5 times annually for an approximate cost of $9,180.

Evaluation

Short-term management of shutter operations is currently being used to reduce temperatures in the Lower American River, but this measure is short-term and does not provide enough operational flexibility to decrease temperatures throughout the year because of the physical configuration of the shutters. Therefore, this measure does not achieve the desired restoration objectives.

The costs associated with this measure are the lowest of all the measures: less than $10,000 per year. This cost is based on increased maintenance associated with more regular removal of the shutters. Because of the cost, the Bureau is currently implementing this measure. To date, there have been no impacts on other resources, but worker safety could become an issue because of increased shutter management operations and possible closures of the road across the dam.

This measure was eliminated from further consideration because it does not achieve the long-term objective of reducing water temperature in the Lower American River; however, this measure is an important part of an overall plan to manage water temperatures in the Lower American River.

4.2.7 Measure 7: Conduct Additional Temperature Monitoring

Background

Currently, there are 2 penstock temperature/flow acoustic meters on Folsom Dam. In addition, there are 2 temperature probes on major tributaries above Folsom Reservoir: one 4 miles upstream on the North Fork of the American River and one 20 miles upstream on the South Fork of the American River.

Description of Action

The additional temperature-monitoring restoration measure proposes purchasing and installing several different temperature-monitoring devices in strategic locations in the lake and the tributaries. The first action of the measure proposes the purchase of a temperature/flow penstock meter on the third penstock of Folsom Dam. In addition, 4 temperature profilers would be purchased to measure water temperatures near the mouths of the South and North Forks, near the center of Folsom Reservoir, and near the face of Folsom Dam. Under this measure, flow and temperature gages (2 each) would also be installed on the South and North Forks near the high-water line. This restoration measure also includes the purchase of a velocity profiler on Folsom Dam, but further analysis would be required before placing that device (figure 4-7). The Bureau has initiated this monitoring program and placed temperature loggers on the South and North Forks, although the South Fork profiler was vandalized. The Bureau is also collecting temperatures at 5 locations every 2 weeks (Hall pers. comm.).

To store the additional data that would result from these temperature and flow monitoring devices, this measure includes the creation and management of a data acquisition system that would be integrated with current monitoring at Lake Natoma. It is assumed that the data collected from these additional devices would shed further light on future structural or operational temperature reduction opportunities. The cost of this measure is estimated to be approximately $300,000.

Evaluation

Additional temperature monitoring is important for understanding how water temperatures vary throughout Folsom Reservoir and how to revise release schedules to meet fishery needs; however, monitoring does not directly achieve the restoration objective of reducing temperatures in the Lower American River. This measure is a cost-effective way to collect data that would be used for future decision-making. No impacts on other resources are anticipated from this measure; therefore it is acceptable. This measure was eliminated from further consideration because it does not directly achieve the long-term objective of reducing water temperature in the Lower American River, but this measure is important as part of an overall plan to manage water and water temperatures at Folsom.

4.2.8 Measure 8: Purchase Water from Upstream Reservoirs

Background

Upstream reservoirs have the capability to provide cold water downstream to Folsom Reservoir and the Lower American River. However, these reservoirs do not have any release constraints that require operators to meet downstream fish temperature objectives. Therefore, cold water stored in these reservoirs could be available for purchase in spring to reduce downstream temperatures for the remainder of the year, particularly in summer.

Description of Action

This measure proposes the purchase of water from upstream reservoir owners in spring that could be stored and delivered (on demand, if necessary) to aid downstream temperature control for fish habitat. The cost estimate of this measure is $1 million–$4 million, depending on the amount and cost of the water acquired.

Evaluation

Purchasing water in the upstream American River watershed is not certain to achieve the restoration objective of reducing water temperatures in the Lower American River. The strategic buying of American River water during winter and spring could result in the delivery of cold water to Folsom and an overall reduction in reservoir water temperatures, but this measure is unreliable because it depends on the delivery of cold water from the upper watershed and the maintenance of coldwater reserves throughout spring and summer. Water purchase contracts might not be able to guarantee the date and temperature of the water released to Folsom Reservoir. Conversely, water releases at the wrong time of year could result in the warming of Folsom Reservoir. The Bureau is concerned about achieving downstream temperature objectives because of water transfers during summer months. Water transfers during the summer effectively deliver warm water to Folsom, and the Bureau is required to release colder water downstream, making management of the coldwater pool more difficult. The extent of potential cooling, or warming, from water purchases and transfers is unknown.

The costs associated with this measure would vary based on the amount and purchase price of water from the upper watershed. Impacts on environmental resources, recreation, and water supply are likely under this measure. The early release of cold water from the upper watershed would result in less instream flow later in spring and summer and lower reservoir levels in summer. Because much of the watershed is regulated with reservoirs, these changes are not likely to have a significant adverse environmental effect, although there may be a shift in vegetation patterns and wildlife habitat. Summer rafters and recreational users of upper watershed reservoirs would be adversely affected, reducing the acceptability of this measure.

This measure was eliminated from further consideration based on its limited effectiveness because of the uncertainty of the delivery window, and because of its low public acceptability.

4.2.9 Measure 9: Normalize Gate Operations

Background

Folsom Dam and Reservoir are managed to fulfill multiple objectives, such as flood control, water supply, fish and wildlife protection, recreation, and power production.

Description of Action

This restoration measure proposes to operate Folsom Dam with the primary objective of maintaining normal or average hydrologic flow. Some flood control objectives could be implemented under this measure, but wildlife protection, recreation, and power production would not be explicitly managed. It is assumed that wildlife would inherently benefit from a system that operates as closely as possible to its normal hydrologic regime.

Evaluation

Normalizing gate operations would reduce water temperatures in the short term but would create large windows of time during which temperatures exceed existing conditions particularly in the late fall. Although this measure could solve the temperature problem for steelhead, it would create additional problems for salmon. Overall, it is not effective at achieving the restoration objective. This measure would be unacceptable because it would not achieve the basic planning constraints required of restoration measures and would result in reduced power generation, reduced water supply, and adverse effects on recreation. Because the operation of Folsom Dam would simulate natural conditions, less water would be available for power generation, the municipal water supply, and recreational use. This measure was eliminated from further consideration because it does not achieve the long-term objective of reducing water temperature in the Lower American River.

4.2.10 Measure 10: Turbine Bypass

Description of Action

This measure proposes that all release flows from the penstocks are diverted to bypass the power turbines, thereby eliminating the increase in temperature that occurs when release flows pass through the turbines. This measure does not propose any other structural or operational changes beyond the future without-project condition of a 1-1-2-2-3 shutter configuration.

Evaluation

Bypassing the turbines would slightly reduce water temperatures in the short term because power generation raises outlet temperatures, but the overall temperature releases are largely limited by the existing shutter system. This measure would not allow for the best management of the Folsom Reservoir coldwater pool because, even under the future without-project condition, large amounts of cold water could be released early in the spring and summer, and fall temperature targets would not be met and the overall restoration objectives would not be achieved. This measure would be unacceptable because it would not achieve the basic planning constraints required of restoration measures; in particular it would cost forgone power generation. This measure was eliminated from further consideration based on its efficiency, acceptability, and completeness constraints.

4.2.11 Measure 11: Installing Temperature Curtains (either at the Nimbus Power Plant intake or plunge zone of Lake Natoma)

Background

Once water is discharged from Folsom Reservoir, it heats up as it moves through Lake Natoma and progresses down the Lower American River. The extent of the water temperature increase in Lake Natoma is not entirely known, though a recent bathymetric survey (e.g., temperature/depth study) and temperature monitoring will soon provide a more comprehensive understanding of water temperatures throughout and downstream from Lake Natoma (Hall pers. comm.). Historical data indicate that median monthly temperatures downstream of Lake Natoma at the Fair Oaks gage for June, July, August, and September were 1.9, 2.1, 2.7, and 1 degrees higher, respectively, than temperatures released from Folsom. However, data from the Fair Oaks gage are somewhat suspect to water planners because the gage is located in a backwater that is likely to contain warmer water. In the past 6 months, a new gage has been placed at Hazel Avenue to monitor temperatures. Preliminary data from this gage and the temperature loggers used in the bathymetric survey indicate that water temperature increases in Lake Natoma may not be as great as expected (Hall pers. comm.).

However, if a substantial increase in water temperatures is resulting in Lake Natoma, a temperature curtain at the plunge zone of Lake Natoma or around the Nimbus power plant intake could help manage cold water as it progresses down the Lower American River. Folsom Dam releases currently mix with Lake Natoma's warmer surface water. This mixing may result in an increase in water temperature passing through Lake Natoma, which increases water temperatures downstream. Additionally, Nimbus Power Plant withdraws the top 15 feet of surface water because a debris wall around the power plant intakes allow withdrawal of water mostly above the elevation 105 ft mean sea level. Surface withdrawals are warmer than what is desired in the Lower American River during the summer and fall providing an opportunity to reduce temperatures discharged from Lake Natoma to the Lower American River.

Description

By installing a surface suspended temperature curtain upstream of the plunge zone, cold water inflows from Folsom will experience less mixing and will be maintained across the depths of Lake Natoma. The plunge zone is the zone where water enters Lake Natoma; its location shifts with surface temperature, flow rate from Folsom, and the elevation of Lake Natoma. A curtain at this location would limit mixing and maintain better temperature stratification in Lake Natoma. This technique has been successfully employed in Whiskeytown Reservoir in northern California.

Similarly, by installing a surface suspended temperature curtain around the power plant intake structure, the coldwater pool in Lake Natoma would be tapped and discharged to the Lower American River. This curtain would minimize the mixing of warm and cold water as the cold water is drawn under the curtain and through the power plant.

The cost for both curtains, assuming the same constraints as the curtain estimate provided for the tributary inflows to Folsom Reservoir, is $752,000.

Evaluation

The effectiveness of the temperature curtains at 1 or both locations in achieving downstream temperature objectives is unknown because it is dependent on the temperature increases in Lake Natoma and the ability of the curtains to regulate the coldwater pool in Lake Natoma. Information regarding temperature increases in Lake Natoma will soon be available, but preliminary results indicate that the temperature increases may not be as large as expected. The installation of a plunge zone temperature curtain in Lake Natoma may not perform the same as in Whiskeytown Reservoir because the Lake Natoma plunge zone is shallow and narrow, limiting cross-sectional area and possibly resulting in an underflow velocity that reduces the effectiveness of the curtain. Furthermore, the overall effectiveness of this measure is constrained by the Folsom Reservoir release temperatures.

Provided the curtains are effective, this measure would be efficient. However, the acceptability of this measure is questionable because of its implementability and its social feasibility. There remain significant technical issues that would need to be resolved and studies that would need to be conducted to validate whether this measure can be implemented. Boat passage across the curtain may reduce the effectiveness of the curtain because of leakage through the lock. Folsom power generation may need to be altered from a peaking power scheme to a partial peaking scheme. Fluctuating water levels, floodflows, operation and maintenance costs, and hydrodynamics would need to be evaluated. A temperature curtain at the plunge zone on Lake Natoma may be socially infeasible because of effects to recreational users. No effects on recreational users would be anticipated for a curtain at the Nimbus Power Plant because the area near the power plant is already restricted.

This measure was eliminated from further consideration because its effectiveness and acceptability are questionable. Because of the remaining issues that would need to be resolved with this measure it is also considered incomplete.

4.2.12 Measure 12: Removing All, or Part of, Submerged Concrete Debris Wall in Front of the Nimbus Power Plant

Background

There is a debris wall near the Nimbus Power Plant intake that is 25 feet deep and extends upward approximately 15 feet from the bottom surface. Water entering the power plant intake must pass over the wall, and it is suspected that the wall increases the mixing of cold and warm water, resulting in the downstream release of warmer water.

Description of Action

By removing the wall or a portion of the wall that is perpendicular to the dam face, water would be directed to move along a deep channel parallel to the dam apron and less mixing may occur. If the portion of the wall that is parallel to the dam face is left in place, it would need to be extended vertically to prevent water from passing over it. The approximate cost of this measure is $200,000.

Evaluation

The effectiveness of this measure is unknown because the extent of mixing at the dam face is unknown. A slight decrease in release temperatures would be expected, but some mixing would still occur. Additionally, there may be an increase in debris loading at the power plant, requiring additional trash-rack cleaning and potential downstream turbidity effects. This measure would be cost effective and acceptable. However, this measure is not anticipated to be effective enough to achieve downstream temperature objectives.

4.2.13 Measure 13: Constructing a Temperature Control Device for Nimbus Dam Spillway Bay(s)

Description of Action

The current configuration of the Nimbus Dam spillway draws warmer surface water over the spillway crest when higher flows bypass the powerhouse. By constructing a temperature control device such as a low-elevation chute to bypass the power penstocks, lower elevation cold water could be released from Lake Natoma. The construction cost of this measure is unknown, although it is anticipated to be relatively inexpensive.

Evaluation

The effectiveness of this measure is unknown because the temperatures of spillway draws are unknown. Furthermore, the timing of use of the spillway would have to be compared with the downstream temperature critical periods. This measure would compliment other measures, but would not be expected to achieve downstream temperature objectives in the Lower American River by itself. This measure would likely be both efficient and acceptable, but at this time, it is incomplete. Because of the limited effectiveness of this alternative, it was eliminated from further consideration.

4.2.14 Measure 14: Modify Channel in Lake Natoma

Description of Action

By identifying and then modifying (i.e., dredging) locations in Lake Natoma that impede the transport of cold water and induce mixing, the coldwater pool in Lake Natoma can be better managed. Downstream of Negro Bar and near Nimbus Dam are 2 likely locations where mixing occurs. The depth and extent of dredging is unknown, although recent bathymetric surveys may provide additional insight to areas of warming and opportunities for channel modification. The costs associated with this measure are unknown, but would likely be moderately expensive.

Evaluation

The effectiveness of this measure is unknown because of the uncertainty surrounding temperatures in Lake Natoma and whether dredging would reduce mixing throughout the lake. This measure is beneficial only when used in conjunction with other proposals.

Modifying the channel in Lake Natoma is not cost effective because there are other less expensive structural and operational measures that could be implemented first. Furthermore, because modification of the channel would result in increased siltation and debris and interruption of recreational use of Lake Natoma, this measure is likely to be unacceptable to the public. For these reasons, this measure was eliminated from further consideration.

4.2.15 Measure 15: Install Pipe from Folsom Tailrace to Nimbus Outlet

Description of Action

By installing a large diameter pipeline to convey water from the Folsom tailrace to the Nimbus Power Plant, coldwater releases from Folsom would be maintained without warming in Lake Natoma and would be conveyed down the Lower American River. The costs associated with this measure are unknown, although they are likely to be moderately expensive.

Evaluation

The effectiveness of this restoration measure is constrained by the operational flexibility of the shutter release temperatures from Folsom. This measure would bypass Lake Natoma and reduce water warming in this segment of the river, but the overall temperature reductions are currently unknown. Because the downstream temperature reductions are unknown and the cost for installing this pipeline is expected to be high, this measure is not cost effective. This measure is technologically feasible, but the construction of a 7-mile pipeline would result in adverse effects on vegetation and water quality and temporary adverse construction effects on recreational uses near construction areas. The high cost and environmental and recreational effects are likely to make this measure unacceptable. Without further analysis of the investments and actions needed for this measure, this measure is considered incomplete. The Bureau's function analysis work group did not recommend this measure for advancement. This measure was eliminated from further consideration based on its acceptability and completeness constraints.

4.2.16 Measure 16: Move Natoma Power Plant and Outlet to Opposite Side of Lake Natoma with Temperature Control Device

Description of Action

Moving the Natoma Power Plant to the opposite side of Lake Natoma would ensure that the power plant outlets are located closer to the hatchery outfall, resulting in lower temperatures, less backwater, and greater downstream current at the hatchery outfall. The costs associated with this measure are unknown, although they are likely to be expensive because major reconstruction of the dam would be required.

Evaluation

This measure could result in some reduction in downstream temperatures in the vicinity of the hatchery outlet, but temperature reductions at Watt Avenue are unlikely under this measure. This measure does not contribute to coldwater-pool management of either Folsom Reservoir or Lake Natoma. This measure was designed to run the coldest water by the hatchery outlet and could result in some benefits in the vicinity of the hatchery outlet, but these benefits have not been quantified. This measure is not cost effective because it would require the substantial reconstruction of Nimbus Dam. Without further analysis of the investments and actions needed for this measure, this measure is considered incomplete. The Bureau's function analysis work group did not recommend this measure for advancement. This measure was eliminated from further consideration based on its effectiveness, acceptability, and completeness constraints.

4.2.17 Measure 17: Placing a Coldwater Barrier in Front of Folsom South Canal

Description of Action

By adding a structure in front of Folsom South Canal, warmer surface water would be conveyed down the canal, maintaining cold water in Lake Natoma for downstream Lower American River use. The costs associated with this measure are unknown, but are not expected to be expensive.

Evaluation

The downstream temperature reductions resulting from this measure are unknown. However, because Lake Natoma temperature increases may not be as large as expected, and because of the small amount of water (approximately 20 TAF) conveyed down the Folsom South Canal, this measure is not expected to be effective at reducing temperatures in the Lower American River as measured at Watt Avenue.

Although this measure is not expected to cost very much, it is not a cost-effective investment because other structural and operational measures provide greater certainty with respect to temperature reductions. The acceptability of this measure is unknown without more information on this measure’s contribution to the problem or solution. If diversions to the Folsom South Canal increase substantially, this measure may need to be revisited. The Bureau’s function analysis work group did not recommend this measure for advancement. This measure was eliminated from further consideration based on its effectiveness and completeness constraints and because it had questionable cost-effectiveness and acceptability.

4.2.18 Measure 18: Building Instream Habitat Improvement Projects Downstream of Nimbus Dam

Description of Action

Adding human-made structures and large woody debris to the Lower American River channel could increase habitat suitability. Woody debris such as root wads anchored in the stream provide structure, cover, and protection for juvenile salmonids. The costs associated with this measure are unknown, although they are not expected to be expensive.

Evaluation

This measure does not affect existing facilities, has no operation and maintenance costs, and will improve habitat; however, it does not achieve the overall objective of reducing temperatures in the Lower American River. It provides a way to improve habitat, but does not contribute to the most limiting habitat variables: flow and temperature.

This measure, while technically possible, could be quite expensive and result in environmental and recreational effects. Short-term construction effects would include increased turbidity and displacement of existing habitat, but these effects are anticipated to be offset with the expansion and enhancement of this habitat. The creation of these habitats could also result in river hazards to boaters, but improved fishing opportunities. Without further analysis of the investments and actions needed for this measure, this measure is considered incomplete. This measure was eliminated from further consideration because it is ineffective at achieving the downstream temperature objectives, is moderately unacceptable at this time without more agency involvement, and is incomplete.

4.2.19 Measure 19: Developing Access for Steelhead above Folsom Dam

Description of Action

By creating a system to introduce American River steelhead to spawning areas above Folsom Dam, the overall steelhead abundance could be increased. Trapping and trucking adult steelhead above the dams or building fish ladders around the dams could provide fish access to the upper watershed. High costs would be anticipated under both methods. The costs associated with this measure are unknown, although they are likely to be expensive.

Evaluation

This measure is ineffective at achieving the project objectives. It is not designed to reduce water temperatures in the Lower American River, but to improve access to spawning habitat in the upper watershed. While this type of restoration ultimately may be considered as part of a comprehensive restoration effort, spawning areas' flow and temperature are currently the limiting factors in the Lower American River.

This measure is not considered cost effective because it does not achieve the project objectives, because of high anticipated cost, and because there are less expensive structural and operational solutions to achieve the project objectives.

While technologically possible, this measure is currently unacceptable because of the costs associated with transferring the fish. While some lessons can be learned from the Columbia River fish passage efforts, there are significant issues that would need to be resolved including: obtaining suitable stock, avoiding the introduction of viruses, evaluating the loss of juveniles to predators, and passage over the dams. Without more information on the investments and actions needed for this measure, this measure is considered incomplete.

This measure was eliminated from further consideration because of its inability to effectively achieve the restoration objective, and because of its acceptability and completeness constraints.

4.2.20 Measure 20: Building Off-Site Habitat Downstream of Nimbus Dam for Steelhead

Description of Action

Restoring and creating habitat along Dry Creek, Buffalo Creek, and the creek along Winding Way could provide additional steelhead habitat in areas that do not currently support steelhead. As part of this off-site ecosystem restoration, additional fish ladders and stream diversions would be required. The costs associated with this measure are unknown.

Evaluation

This measure does not affect existing facilities, has limited operation and maintenance costs, and will improve habitat; however, it does not achieve the overall objective of reducing temperatures in the Lower American River. It provides a way to improve habitat, but does not contribute to the most limiting habitat variables: flow and temperature.

This measure, while technically possible, could be quite expensive and result in environmental effects on the fish themselves. Short-term construction effects would include increased turbidity and displacement of habitat within creeks, but these effects are anticipated to be offset by the expansion and enhancement of this habitat. The availability of suitable sites, the number and types of fish passage devices, and the funding for these restoration efforts are unknown. Without further analysis of the investments and actions needed for this measure, this measure is considered incomplete. This measure was eliminated from further consideration by the work group, and was also eliminated from further consideration because it is ineffective at achieving the downstream temperature objectives, is moderately unacceptable at this time without more agency involvement, and is incomplete.

4.2.21 Measure 21: Improving Real-Time Temperature Monitoring

Description of Action

By adding temperature profile stations in Lake Natoma at Negro Bar, Willow Creek, and Alder Creek, and upgrading the hatchery temperature gage to operate 24 hours per day, more information could be provided to make coldwater release decisions. The recent bathymetric survey helps supplement this information by providing detailed information on the temperature increases in Lake Natoma and will ultimately be provided as a map of cold water in the lake.

Evaluation

While this measure is important for overall management decisions and responding to fishery resource needs, it does not achieve the objective of reducing water temperatures in the Lower American River. This measure is otherwise efficient, acceptable, and complete and is currently being implemented by the Bureau. This measure is important for overall restoration objectives, but was eliminated from further consideration in this document because of its inability to achieve the effectiveness criteria.

4.2.22 Measure 22: Diverting Flows from Folsom South Canal into the Cosumnes River

Description of Action

By diverting 30 cfs of Folsom South Canal flows into the Cosumnes River for a 3-month period during the fall, Cosumnes River instream flow conditions would be enhanced for spawning chinook salmon. This measure serves to improve existing habitat on the Cosumnes River and may increase overall chinook and steelhead habitat in California. The costs associated with this measure are unknown.

Evaluation

This measure would be effective at improving overall steelhead habitat in the Cosumnes River, but would not achieve the overall objective of improving fishery habitat in the Lower American River. The cost of this measure is unknown, but the measure is unlikely to be cost effective until other measures have been implemented. This measure is unacceptable because it does not resolve achieve the current Lower American River fishery needs, and once diversions were initiated they would likely need to be maintained. The Bureau's function analysis work group did not recommend this measure for advancement. This measure was eliminated from further consideration based on its effectiveness, acceptability, and completeness constraints.

4.2.23 Measure 23: Performing a Quick Evaluation of Current Operations

Description of Action

This measure was designed to provide the Nimbus Hatchery and Open River work group an opportunity to determine whether there were any opportunities to mitigate unmet temperature requirements under current operations. The intent was to maximize the use of Folsom's coldwater pool by implementing long-term temperature scheduling with existing structures.

Evaluation

The work group determined that this measure was ineffective and that all available cold water would be utilized before fall chinook salmon spawn. It further concluded that current operations are a function of real-time decisions, and a predetermined operating schedule would not be responsive to endangered species needs. The work group did not recommend this measure for further consideration.

4.2.24 Measure 24: Coordinating Techniques and Tools to Optimize Use of Cold Water

Description of Action

This measure is designed to coordinate a variety of techniques and tools to optimize the use of cold water from Folsom. Specifically, the work group recommended integrating existing tools, such as existing temperature probe data, use of the shutters on Folsom, control of the releases from Folsom, and the use of CVPIA b(2) water, with SWRI's computer modeling for scheduling in-river temperature reductions. The work group also recommended expanding this analysis to include other items like installing the coldwater barrier on the Folsom South Canal and installing new temperature probes at Negro Bar, Willow Creek, and Alder Creek. The cost associated with this measure is dependent on the cost associated with the new operational or structural techniques that are used.

Evaluation

The coordination of multiple techniques and tools could result in downstream temperature reductions in the Lower American River. However, SWRI has simulated temperature scheduling and determined that temperature reductions are dependent on the operational flexibility of the shutters on Folsom. Furthermore, existing temperature data are already considered when making water release decisions.

This measure is likely to be cost effective, but is dependent upon the combination of measures that is employed. The collection of additional data and research of other temperature control measures by the Bureau and additional analysis of the shutters by SAFCA will help determine the overall efficiency of this measure.

This measure would be acceptable because it could use the most effective and efficient measures to achieve temperature reductions. However, data continue to indicate that the shutters are a key limiting factor to managing Folsom's coldwater pool under all temperature conditions and during all year types, and that all other measures are further enhanced by modernization of the shutters.

A complete integration of structural and operational management techniques has not been done to date. Additional investments, structural and intellectual, are needed to determine the optimal mix of techniques and tools to optimize the coldwater pool of Folsom Reservoir and Lake Natoma. The Bureau, AROG, SAFCA, and SWRI are currently working together to determine and accomplish the actions necessary to create a complete picture of temperature control throughout the Lower American River, although current data suggest that the temperature shutters on Folsom are the largest overall constraint. This measure will continue to be evaluated in terms of overall Lower American River restoration but was eliminated from further consideration in this analysis because it is incomplete.

4.3 Identification of Preferred Restoration Measure

Based on the screening process described above, the preferred temperature restoration measure is the modernization of the temperature shutters beyond the future without-project condition (i.e., 1-1-2-2-3 shutter configuration) to a 7(1)-2 shutter configuration. This measure provides the best overall value to ensure reliable, regular, and adjustable releases of cold water to reduce Lower American River water temperatures. The coordination of techniques and tools to optimize the use of cold water is also being considered by the Bureau as a technique to optimize cold water for restoration objectives, but the coordinated measure is dependent on the modernization of the temperature shutters, and therefore only the shutter measure was advanced. Additional screening was conducted to determine the most appropriate type of modernization; these techniques are described in section 5.

SECTION 5.0

RESTORATION MEASURE SELECTED

Based on the screening process described in section 4, modernization of the shutters is the best approach to achieving Lower American River temperature objectives. This section provides an overview of manual and mechanized operations, a summary of the fishery analysis prepared by Surface Water Resources, Inc. titled "Temperature and Fishery Analysis of Mechanized Temperature Control Device at Folsom Dam" (appendix A), a study on modernization alternatives prepared by HDR Engineering, Inc. titled "Technical Memorandum – Temperature Shutters Study of Design Options and Feasibility Report/Engineering Appendix," (appendix B), and identification of the preferred restoration measure.

5.1 Overview of Manual and Mechanical Operations

There are 2 available modernization approaches for the 7(1)-2 configuration: manual and mechanized. Both approaches require significant capital investment ($9 million–$20 million). These approaches have identical shutter configurations, but their annual implementation cost and ease of operation varies. Based on fishery and engineering analysis, and a comparison of the advantages and disadvantages of these approaches, a preferred restoration measure was selected.

5.1.1 Manual Operation

Modernizing the shutters to accommodate manual operation poses significant challenges including both structural and operational problems. Structurally, there is limited space on the deck above the shutters and adjacent to the track containing the shutters. Currently there are 3 "stems" which support each series of shutters (i.e., the first stem is currently attached to 3 shutters, the second stem is attached to 2 shutters, and the third stem is attached to 4 shutters). When a series of shutter is pulled up, a 13-foot section of the stem is removed and hung from the deck. Pins are then used to secure the stems and shutter in place. The number of stems can be expanded to accommodate 5 stems in the without-project future condition, but cannot be expanded further due to space limitations on the deck of the shutters and interference between the locking mechanisms of the stems. Each series of additional stems beyond 3 results in a cantilevering effect and eccentricity that reduce the ability to raise and lower the shutters in the track. The existing location of the trash rack also prohibits the expansion of this system.

Operationally, if this system were constructed, it would require a field crew of 3 maintenance personnel approximately 16-24 hours to adjust the shutters and may involve the temporary closure of Folsom Dam Road. The shutters would have to be moved approximately 12 times per year with a majority of these movements in the summer and early fall. The Bureau has indicated that additional shutter changes, particularly daily or weekly changes, would not likely occur because 2-weeks scheduling time is needed to ensure the maintenance personnel are available (Johnson pers. comm.). Because of the intermittent control of this shutter system and inability to regularly adjust and refine the levels of the shutters and therefore reduce temperatures at critical periods, the USFWS is not supportive of this measure (DeHaven pers. comm.).

The approximate first costs for manual shutter operation are $9 million and the annual cost for manual shutter adjustment is $44,000. While this measure has the advantage of reduced capital investment compared to mechanization, it has the following disadvantages:

- overall feasibility,
- possible disruption of traffic flow,
- increased operation and maintenance,
- labor intensity, and
- delayed temperature adjustment response time.

This measure was eliminated from further consideration because of its overall feasibility, daily or weekly shutter changes could not be performed, and because slow shutter adjustment periods would not maximize the benefits to the fishery.

5.1.2 Mechanized Operation

Mechanized operation of the shutters includes partial or complete mechanization of the shutters that would eliminate the need for manual operations. Mechanized operation would involve some limited manual oversight by 1 staff member to monitor temperatures and to ensure that equipment is functioning properly. With mechanized shutter modernization to a 7(1)-2 shutter configuration, the shutters could be moved as frequently as desired. The approximate first cost for mechanized shutters is $16.3 million annual cost for mechanized operation is $2,000.

This alternative has following advantages:

- allow for real-time temperature operation based on actual fishery needs,
- rapid response to power generation needs while meeting temperature requirements,
- reduction in staffing maintenance needs, and
- optimal cold-water pool management.

This alternative has the following disadvantage: increased capital investment as compared to manual modernization.

5.2 Summary of Fishery Analysis

The fishery benefits of a mechanized temperature control device were analyzed in detail by Surface Water Resources, Inc. The analysis included a comparative evaluation of:

- existing condition (3-2-4 shutter configuration),
- no project-future condition (the future 1-1-2-2-3 shutter configuration),
- modernization of the shutters for manual operation (7(1)-2 shutter configuration), and
- modernization of the shutters for mechanized operation (7(1)-2 shutter configuration).

Several modeling tools were evaluated to characterize temperatures in the Lower American River including; the Bureau reservoir and river monthly temperature models, the automated temperature selection procedure, and the weekly cold water pool management model (CWPMM). The CWPMM was selected for use because it allowed analysis of shutter position changes more frequently than the other models. Since the CWPMM is designed to work for a single year three weekly time interval data sets were developed to represent years with favorable, moderate, and adverse hydrologic/meteorological conditions for temperature management purposes. These data sets were then used to perform three temperature simulations, one for each set of conditions. The temperature results of these model runs were then input into a salmon mortality model to predict salmon fishery impacts. The simulations were not performed to maximize the beneficial impacts to salmon but to identify the "best" year around balance between salmon and steelhead in the Lower American River.

Table 5-1 summarizes the results of the salmon mortality modeling, here the smaller the percent mortality the greater number of salmon that survive. These values do not identify the most beneficial solution for all species in the Lower American River, but provide an indication of the benefits that can be achieved through improved cold-water pool management. (Surface Water Resources 2001b.)

The values largely follow the expected trends of lower mortality in more favorable years and lower mortality with improved cold-water pool management. The 3-2-4 configuration does not show the expected pattern of results between the year types because of a large increase in Folsom release in the developed data set during the summer when the modeling asked for a change in shutter conditions. This resulted in a large cold-water release from the reservoir, which depleted the cold-water pool and severely limited the ability to meet temperature targets throughout the rest of the year. This mid summer increase in release was due to the specific favorable year release pattern used to develop the favorable year input data and is not typical of all favorable years. This result did not occur in the other shutter configurations modeled because they offer enough flexibility in withdrawal elevation to avoid large cold-water releases during the same high release period. (Surface Water Resources 2001b.)

TABLE 5-1. Annual Salmon Mortality (%)

Year Type	Existing (3-2-4)	No Project: Future Condition (1-1-2-2-3)	Modernization: Manual (7(1)-2)	Modernization: Mechanized (7(1)-2)
Favorable	14.29	8.69	5.92	5.17
Moderate	10.13	11.87	6.07	6.55
Adverse (Drought)	16.17	19.99	13.60	8.97

Based on this analysis, a modernized shutter system with a 7(1)-2 configuration will likely result in benefits to salmonids in the Lower American River due to improved water temperatures. Overall, the mechanized shutter system will result in the greatest benefits because it provides the greatest operational flexibility.

5.3 Summary of Engineering Analysis

After identification of the preferred restoration measure, five options were developed and analyzed by HDR Engineering, Inc., in their Technical Memorandum - Folsom Dam Temperature Shutters - Study of Design Options and Feasibility Report/Engineering Appendix (appendix B). These options outline different structural solutions available that would meet the objectives of the preferred restoration measure. Each of these alternatives were further analyzed and screened by HDR Engineering, Inc.

The five options analyzed are summarized below:

- Option 1 – Future without Project. This option assumes that the shutters would be operated in the proposed Folsom Reoperation mitigation system, which is a 1-1-2-2-3 configuration, and assuming six shutter changes a year.
- Option 2 – Multi-Track Slide Gates. This option provides for five 26-foot-high slides gates, traveling on a separate track, and able to be moved up or down in 13-foot increments to provide a 26-foot opening at any level.
- Option 3 – Curtain Walls with Movable Opening. This option includes three variations of a curtain wall with a movable 26-foot opening. This would be a continuous curtain wall of conveyor belting of hypalon.
- Option 4 – Wicket Gates on Vertical Shafts. Option 4 consists of nine 13-foot-high wicket gates on vertical shafts. The gates would be rotated 90 degrees to open or close.
- Option 5 – Shutters on Horizontal Shafts. Option 5 consists of nine 13-foot-high shutters on horizontal shafts.

A number of different selection criteria were used to compare the options against one another. Those criteria included cost, schedule, ease of operation, flexibility, impact on power production, reliability, and environmental impacts. The definition of each of those criteria is as follows:

- Cost – included cost of construction, engineering, administration, and an estimate of operation and maintenance and major replacement costs.
- Construction Schedule – considers potential power losses during construction, the time frame necessary for engineering, bidding, equipment procurement, and construction.
- Ease of Operation – includes the size of the crew needed, actions and time required to move shutters, and verification that shutters are properly positioned.
- Flexibility – Due to the conceptual nature of some of the measures, the weighting of the selection criteria was subjective.

- Reliability – includes a low probability of breakdown and whether or not it is simple/quick to repair.

Based upon these criteria, a decision matrix was constructed to determine the most preferred option. Each criteria was given different weighting: reliability 28 percent, ease of operation 24 percent, flexibility 19 percent, cost 14 percent, construction schedule 10 percent, and environmental impacts 5 percent. The analysis of the options based upon these weighted criteria would result in a preferred option of Option 2, Multi-Track Slide Gates.

In general, Option 1 does not meet the restoration objectives, and Options 3, 4, and 5 have significant engineering concerns relating to reliability, ease of operation, and flexibility, and would therefore be less effective than Option 2.

5.4 Preferred Restoration Measure

Based upon the advantages and disadvantages, the fishery analysis, and the engineering analysis described above, Option 2, Multi-Track Slide Gates, was determined to provide the best value and certainty for cold-water pool management for chinook salmon and steelhead in the Lower American River. For these reasons, Option 2 will be the assumed design for planning purposes, but other designs may be considered during the detailed design of the project. The costs associated with this option range from $9 million to $20 million. Specific suboptions illustrating different configuration of the mechanized sliding shutters are described in greater detail in appendix B.

SECTION 6

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the U.S. Army Corps of Engineers' (Corps 1
evolutionarily significant unit (ESU) 2
National Marine Fisheries Service (NMFS) 2

U.S. Fish and Wildlife Service (USFWS) 2
Lower American River Task Force—Fisheries and Instream Habitat Working Group (FISH Group) 2
California Department of Fish and Game (CDFG) 2
California Department of Water Resources (DWR) 2
U.S. Bureau of Reclamation (Bureau) 2
State Water Resources Control Board (SWRCB) 2
river mile (RM) 5
American River Flood Control District (ARFCD) 5
Sacramento Area Flood Control Agency (SAFCA) 5
American River Parkway (Parkway) 5
California State Fair and Exposition Center (Cal Expo 5
Central Valley Project (CVP) 6
Sacramento River Flood Control Project (SRFCP) 6
cubic feet per second (cfs) 6
thousand acre feet (TAF) 7
young of the year [YOY] 13
trichloroethylene (TCE) 14
River Corridor Management Plan (RCMP) 16
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